A SYSTEMATIC REVIEW OF MULTIFUNCTIONAL STREETS

Final research report

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CONTENT

Summary

Cities consist of 20-30% streets, a gigantic infrastructure that must be maintained and developed. As such, they have the potential and obligation to contribute to tackling contemporary challenges, such as increasing urbanization and climate change. Multifunctional streets are introduced as an answer to these challenges by designing them to fulfil multiple functions. They should not only be traffic infrastructures, but also lively and inclusive public places, carriers of economic development, ecological corridors supporting ecosystem services and providing smart technical infrastructures.

A state-of-the-art, quantitative systematic review of scientific literature on the theme of multifunctional streets was conducted, including papers published during the last 10 years. This review is part of a 3-year research project (2019–2021) named: "Smart streets" (Smarta gator) led by Alexander Ståhle (KTH Royal Institute of Technology) and financed by Vinnova (Swedish governmental agency for Innovation systems). The research project aims to develop a Street Multifunctionality Index (Gatufunktionsindex) to assess how existing and planned streets combine five different street functions - Social, Ecologic, Economic, Technical and Traffic - and also produce design guidelines for the design of future multifunctional streets.

The aim of the systematic review is twofold. First, to assess the degree in which the multifunctionality of streets is addressed in recent literature and provide an overview of the field, by identifying where the general literature on the subject is trending, which are the recurrent issues studied, what themes are missing or being understudied. Second, the review aims to identify the physical factors which have been empirically proven to support the different street functions, and especially those which support multiple functions. The second aim is pursued through focused thematic reviews, which complement the general overview of the field.

A screening of 3782 scientific papers based on titles and abstracts resulted in the selection of 1172 full papers to be included in the survey. The results showed that most papers do not study street multifunctionality, but rather focus on one or two street functions. The functions mostly studied is the Technical (27%) and Ecological (25%), closely followed by the Social function (22%). The least studied function is the Economic (13%), which calls for more attention.

Within the 1172 papers, 311 are empirical studies focusing on the impact of streets on several socioeconomic and ecological issues. The effects on Health (39%) and Traffic safety (21%) are studied the most, followed by the effects on Biodiversity and Microclimate (12%), Liveability (9%) and Security (4%). Again, the least studied is the economic impact, for example on property values and housing prices (3%).

The empirical studies are especially valuable, since we can use them to identify the physical factors which have been empirically proven to support the different street functions, and especially the ones which support multiple functions.

Two parallel thematic reviews were dedicated to Liveability and Traffic safety, two important variables of the Social function, interrelating yet often conflicting. The parallel reviews identified the physical factors that support Liveability and Traffic safety. Moreover, the reviews identified 7 physical factors that support both Liveability and Traffic safety, and thus have an additive multifunctionality value. These are network connectivity, physical elements which reduce car speeds (e.g. traffic calming features), wide sidewalks, separate bike lanes, the presence of commercial and pedestrian oriented uses, frequent pedestrian crossings, narrow car lanes and short crossing distance.

Another thematic review focused on the multifunctional benefits of street greenery, that are not only ecological (e.g. biodiversity, microclimate), but also social and economic. Most papers showed the beneficial presence of street trees followed by street shrubs and bushes. However, the review brought attention to the conflicting effects of street greenery, or even the disbenefits that can emerge if the contextual factors are not taken into account in the choice of greenery (e.g. location, orientation, local weather conditions, street proportions).

These thematic reviews give valuable input to the Smart Street project, both for the selection of the indicators included in the Street Multifunctionality Index, and for the development of the Multifunctional Street Guidelines.

To support the development of the Street Multifunctionality Index, a special thematic review was dedicated to 8 existing street rating systems and indices that evaluate the performance of streets in relation to specific issues, for example walkability, traffic safety or the environment. The review compared the selection of indicators and the evaluation method or ranking system used to categorise streets.

The multiple focused reviews are particularly interesting as they bring forward the potentials and at the same time challenges of the multifunctionality concept and its potential practical application. When the aim is to increase the multifunctionality of streets, it is key to highlight both the positive synergies, as well as the conflicts between the different street functions. By supporting the synergies and resolving the conflicts, we can promote multifunctionality, a necessary step towards more sustainable cities.

Sammanfattning

Städer består till 20-30 procent av gator, en gigantisk infrastruktur som måste underhållas och utvecklas. Som sådan har gator potentialen och skyldigheten att bidra till lösningar av samtida utmaningar, såsom ökad urbanisering och klimatförändringar. Multifunktionella gator introduceras som ett svar på dessa utmaningar. Genom att utforma gatorna för att uppfylla flera funktioner blir de inte bara trafikinfrastrukturer utan också livliga och inkluderande offentliga platser, bärare av ekonomisk utveckling, ekologiska korridorer som stöder ekosystemtjänster och tillhandahåller smart teknisk infrastruktur.

En kvantitativ systematisk genomgång av vetenskaplig litteratur på temat multifunktionella gator genomfördes, inklusive artiklar publicerade under de senaste 10 åren. Denna granskning är en del av ett treårigt forskningsprojekt (2019–2021) med namnet "Smart streets" (Smarta gator), som leds av Alexander Ståhle (KTH) och finansieras av Vinnova (Svenska myndigheten för innovationssystem). Forskningsprojektet syftar till att dels utveckla ett Gatufunktionsindex för att bedöma hur befintliga och planerade gator kombinerar fem olika gatufunktioner – Socialt, Ekologiskt, Ekonomiskt, Tekniskt och Trafik, dels producera designriktlinjer för utformningen av framtida multifunktionella gator.

Syftet med den systematiska granskningen är dubbelt. För det första att bedöma om gatornas multifunktionalitet är belyst i ny litteratur och ge en översikt över fältet genom att identifiera trender i den allmänna litteraturen om ämnet, vilka återkommande frågorna som studerats, vilka teman som saknas eller underskattas. För det andra syftar granskningen till att identifiera de fysiska faktorer som empiriskt har visat sig stödja de olika gatufunktionerna, och särskilt de som stöder flera funktioner. Det andra målet realiseras genom fokuserade tematiska översikter, som kompletterar den allmänna översikten över fältet.

En screening av 3782 vetenskapliga artiklar baserad på titlar och sammanfattningar resulterade i 1172 artiklar som inkluderades i kartläggningen. Resultaten visade att de flesta artiklar inte studerar multifunktionalitet på gatan utan snarare fokuserar på en eller två gatufunktioner. De funktioner som mest studeras är de tekniska (27%) och ekologiska (25%), följt tätt av den sociala funktionen (22%). Den minst studerade funktionen är den ekonomiska (13%), som kräver mer uppmärksamhet.

Av dessa 1172 artiklar är 311 empiriska studier som fokuserar på gatornas inverkan på flera socioekonomiska och ekologiska frågor. Effekterna på hälsa (39%) och trafiksäkerhet (21%) studeras mest, följt av effekterna på biologisk mångfald och mikroklimat (12%), livskvalitet (liveability) (9%) och säkerhet (4%). Återigen är den minst studerade den ekonomiska effekten, till exempel på fastighetsvärden och bostadspriser (3%).

De empiriska studierna är särskilt värdefulla, eftersom vi kan använda dem för att identifiera de fysiska faktorer som empiriskt har visat sig stödja de olika gatufunktionerna, och särskilt de som stöder flera funktioner.

Två parallella tematiska granskningar ägde rum. Den ena studerade gatornas livskvalitet och den andra gatornas trafiksäkerhet, två viktiga variabler för den sociala funktionen. Genom dessa parallella granskningar identifierade vi de fysiska faktorer som stöder livskvalitet och trafiksäkerhet. Dessutom identifierade granskningen sju fysiska faktorer som stöder både livskvalitet och trafiksäkerhet och därmed har ett additivt multifunktionellt värde. Dessa är ett tätt gatunätverk, fysiska element som minskar bilhastighet (t.ex. trafikreducerande funktioner), breda trottoarer, separata cykelfält, närvaron av kommersiella och fotgängarorienterade funktioner, frekventa övergångsställen, smala bilkörfält och kort korsningsavstånd.

En annan tematisk granskning fokuserade på de multifunktionella fördelarna med gatugrönska, som inte bara är ekologiska (t.ex. biologisk mångfald, mikroklimat) utan också sociala och ekonomiska. De flesta artiklar visade den fördelaktiga närvaron av gatuträd följt av buskar. Granskningen uppmärksammade emellertid de motstridiga effekterna av gatugrönskan, eller till och med de nackdelar som kan uppstå om de kontextuella faktorerna inte beaktas vid valet av grönska (t.ex. plats, orientering, lokala väderförhållanden, gatubredd). Dessa tematiska granskningar ger värdefull information till forskningsprojektet Smarta Gator, både för val av indikatorer som ingår i Gatufunktionsindex och för utvecklingen av de multifunktionella designriktlinjerna.

För att stöda utvecklingen av Gatufunktionsindex har en särskild tematisk granskning ägnats åt åtta befintliga gatuklassificeringssystem och index som utvärderar gatornas prestanda i förhållande till specifika frågor, till exempel gångvänlighet (walkability), trafiksäkerhet eller miljö. Granskningen jämförde urvalet av indikatorer och den utvärderingsmetod eller det rankningssystem som användes för att kategorisera gator.

Granskningar med flera fokus är särskilt intressanta eftersom de tar fram potentialerna och samtidigt utmaningarna i multifunktionskonceptet och dess potentiella praktiska tillämpning. När målet är att öka gatans multifunktionalitet är det viktigt att lyfta fram såväl positiva synergier, som konflikterna mellan de olika gatufunktionerna. Genom att stödja synergierna och lösa konflikterna kan vi främja multifunktionalitet, ett nödvändigt steg mot mer hållbara städer.

1. INTRODUCTION

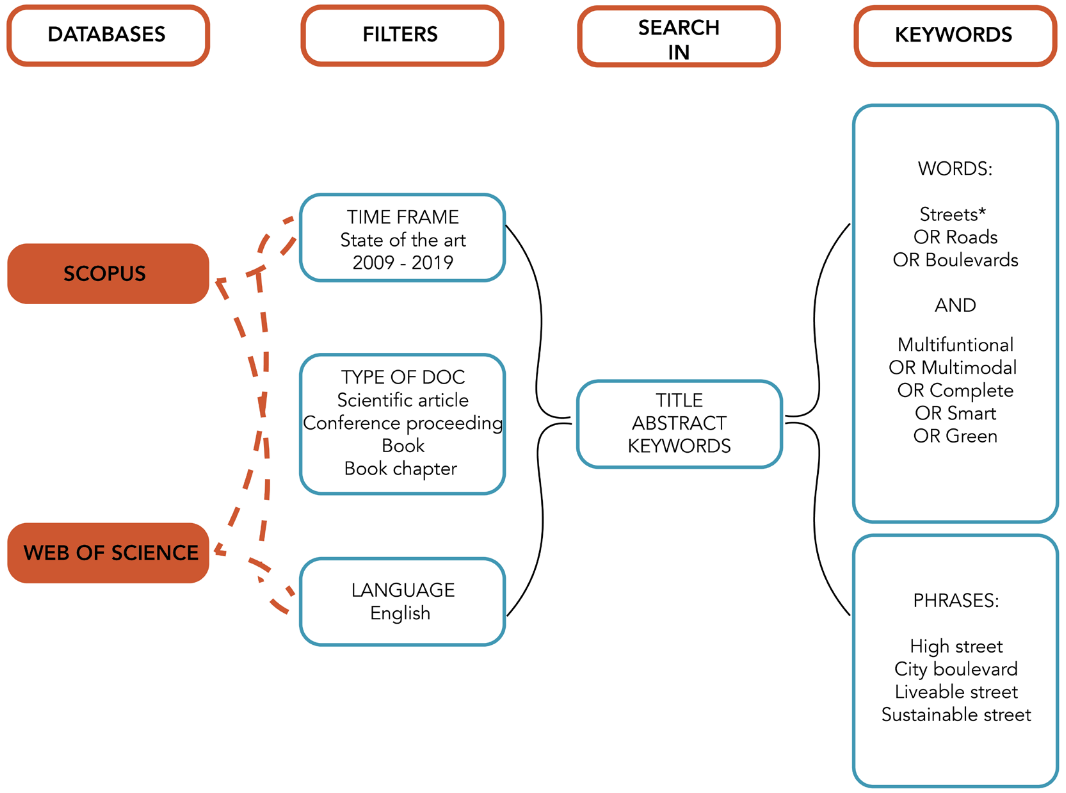
Cities consist of 20-30% streets, a gigantic infrastructure that must be maintained and developed. As such, they have the potential to contribute to tackling contemporary urban challenges related to climate change, biodiversity losses, health problems and well-being that all place. Multifunctional streets are introduced as an answer to these challenges, as they can fulfill this multitude of functions; they are not only traffic infrastructures, but also lively and inclusive public places, carriers of economic development, ecological corridors supporting ecosystem services and lines of technical infrastructures including street and traffic lighting, electrical power, signalization etc.

This report presents a state-of-the-art, quantitative, systematic review of scientific literature on the theme of multifunctional streets. It is part of a 3-year research project (2019-2021) named “Smart streets” (Smarta gator). The project is led by Alexander Ståhle (KTH Royal Institute of Technology) and financed by Vinnova, the Swedish governmental agency for Innovation systems (Ståhle 2019). It aims to develop design guidelines for the design and planning of future multifunctional streets, either in new developments or via retrofits. Furthermore, the project aims to develop a Street Function Index (Gatufunktionsindex) to assess how existing and new streets combine five different street functions - Social, Ecologic, Economic, Technical and Traffic – and thus support multifunctionality.

Ståhle (2019) https://smartagator.wordpress.com/2019/02/20/klartecken-for-sveriges-storsta-forskningsprojekt-om-framtidens-gator/

Within the larger research project, the aim of the literature review is twofold: first, to assess the degree in which the multifunctionality of streets is addressed in recent literature and provide an overview of the field by identifying where the general literature on the subject is trending, which are the recurrent issues studied, which are the clusters of themes emerging and what themes are missing or being understudied. Second, since one of the products of the research project is to provide guidelines for urban design and planning practice, the review aims to identify the physical factors which have been empirically proven to support the different street functions, and especially those which support multiple functions. This second aim is pursued through focused thematic reviews, which complement the general overview of the field.

Figure 1.
Search method



** all generatives are icluded (e.g. streets, multi-modal)*

2. SYSTEMATIC REVIEW OF SCIENTIFIC LITERATURE

A first qualitative search in scientific literature to set up the criteria for the systematic review, shows that there is no generally used term to describe multifunctional streets. Different terms are used depending on the geographical context. For example, in the USA the term used is "Complete streets", while in Australia it is "Smart roads". "Boulevards" and "Liveable streets" are often used in the European context, as well as the older term "High streets" relating mostly to the UK. The main focus in literature on Complete streets, Smart roads, Boulevards, Liveable streets and High streets is on multimodality, meaning the combination of different modes of travel, including cars, public transport, cycles and pedestrians, while all the social, economic and ecological other functions are either missing or studied separately such as the High streets, where the main function addressed is the economic. Literature discussing "Green streets" are the ones that come closest to what is aimed for in this study, where the ecologic function is dominant, but the transport and social function are also addressed.

The preliminary indication is that the multifunctionality of streets is not a topic which has been studied a lot in scientific literature. Multimodality on the other hand is a growing subject especially in transport studies, as well as topics related to future mobility (Autonomous vehicles, Vehicular ad-hoc networks VANET, Intelligent Transport Systems etc).

The diversity of terms as highlighted above is adapted to define the key words used for the systematic review to ensure that we include literature from all geographic regions, and so escape the bias of using only, for example, US-based research.

Research project "Smart Streets"
Since the aim and the end product of the research project is to provide design guidelines and an assessment tool (i.e. the Street Function Index) for the urban design and planning practice, the objective of the review is aligned to synthesise the relevant scientific literature, focusing on design principles and spatial features that have the ability to positively contribute to solving contemporary urban challenges related to climate change, biodiversity losses, health problems and well-being..

The different themes that are reported when reading the papers are related to the different "functions" that a multifunctional street should arguably accommodate, as proposed in the research project:

- Traffic function – the street as a multimodal traffic infrastructure, providing equal access to all modes of travel (e.g. car, cycles, pedestrians)
- Technical function - the street as technical infrastructure, including aspects such as materialisation, pavements, lightning, etc.
- Social function – the street as an inclusive social arena creating places to meet
- Economic function – the street as market creating potential for retail and service
- Ecological function – the street as environmental incubator creating potential for climate adaptation and other ecosystem services

Before arriving at in depth synthesis on different themes, the literature review also provides a quantitative survey of the larger body of literature by reporting on the trends and the common or recurrent issues studied, the clusters of themes emerging, and the themes that are missing or being understudied.

Review method
Since the study of multifunctional streets is a rather new theme and since the guidelines and conclusions need to be relevant for current and future planning, the review is a State-of-the-art review, including only texts from the last 10 years (2009-2019).

The keywords used for the search are defined based on the recurrent terms used to describe multifunctional streets as discussed above. The following keywords are used:

Figure 2.
Prisma statement

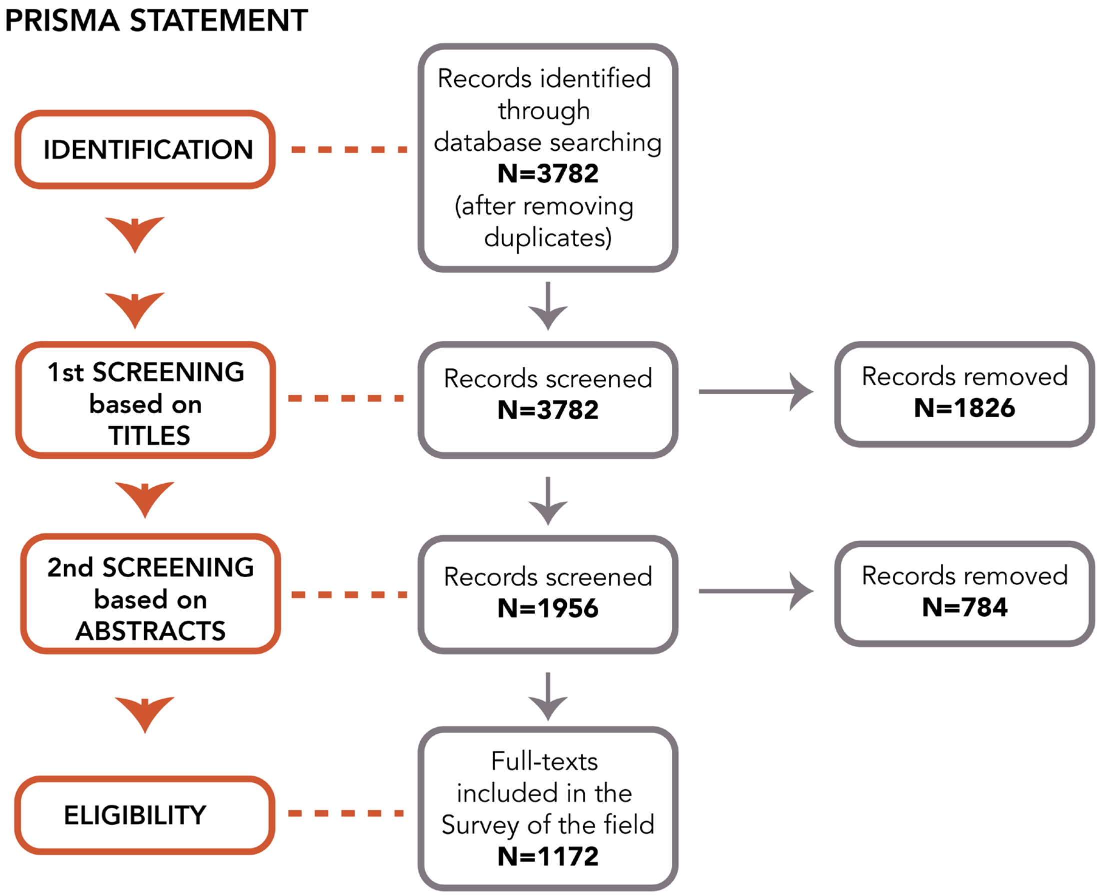
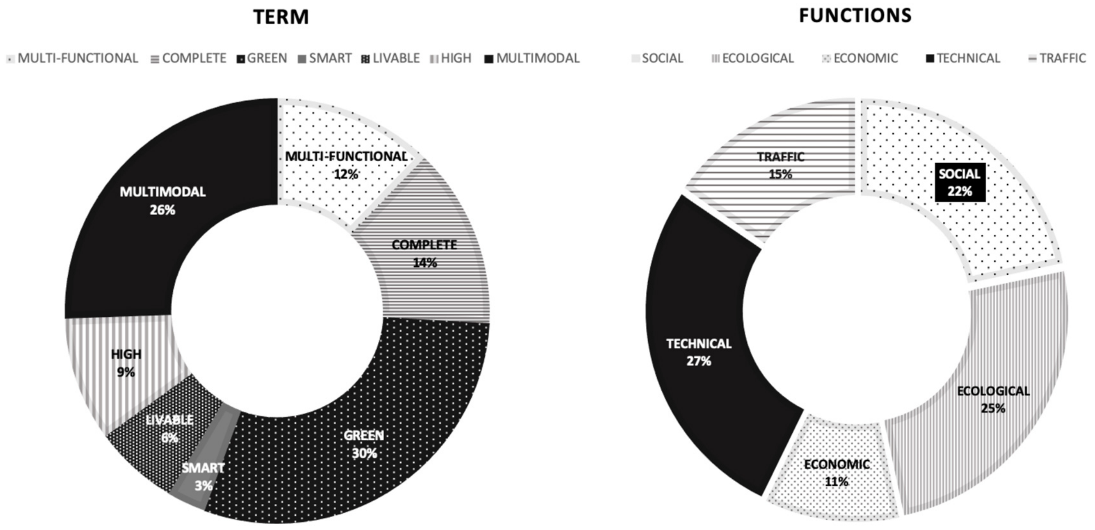


Figure 3.
Terms used for multifunctional streets (left) and functions in focus in 1172 papers (right).



- (Smart OR Complete OR Green OR multifunctional OR multimodal) AND (streets OR roads OR boulevards)
- Sustainable streets (as phrase)
- High streets (as phrase)
- City boulevard (as phrase)
- Liveable streets (as phrase)

All generative words are included (e.g. streets, roads, multi-modal).

The databases used are Scopus and Web of Science and various text types are included based on guidelines regarding systematic reviews. Besides scientific journal articles, conference papers are included to have a more comprehensive review and, books to provide a more stable source of information and developing background knowledge (Moher et al. 2009). Thus, scientific journal article, papers in conference proceedings, book chapters and books are included (all English). Guidebooks, policy papers, practice papers, reports and popular journals, however, are excluded from the selection.

Quantitative overview of the result of the systematic review. Survey of the field
Based on the search words above, 3782 unique scientific papers are filtered from Web of Science and Scopus. Next, a screening of the titles follows based on the general relevance of the papers, which resulted in a shortlist of 1956 abstracts (figure 2).

The Title screening also excluded papers on the theme of Future trends(Trender, innovationer och framtidsscenarier) that is part of another work package of this project (WP3). For example, it excluded papers related to:
- Automatic vehicles, self-driving vehicles
- VANET (Vehicular ad-hoc networks)
- ITS (Intelligent transportation systems)

In the third step, the 1956 shortlisted abstracts are, in case they are still included after abstract reading, classified by noting (1) the term used for multifunctional street; (2) street functions that are addressed; (3) type of study; (4) geographical context. In the case of empirical studies (type of study), also the main societal, environmental or economical effect (e.g. health, microclimate, walkability) is recorded.

Out of the 1956 screened abstracts, 784 are assessed as irrelevant to the focus of the review (e.g. large-scale freight, route planning apps, smart tolls and pricing, in-vehicle support), resulting in a final set of 1172 full papers are found eligible for further reading and thus included in the survey of the field (Stavroulaki and Berghauser Pont 2019a).

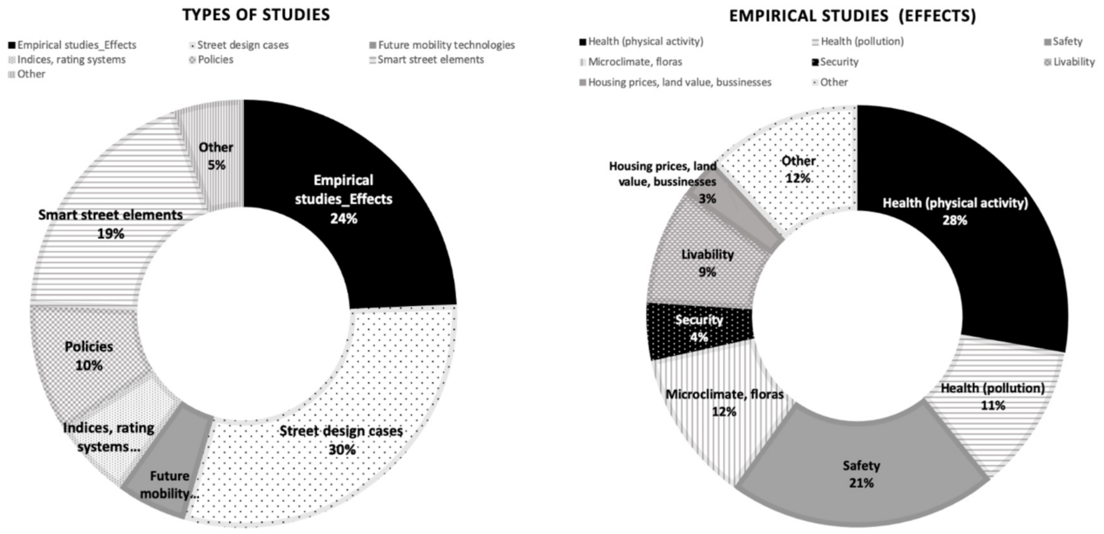
Stavroulaki and Berghauser Pont (2019a) https://smartagator.wordpress.com/2019/06/17/vad-sager-1000-vetenskapliga-artiklar-om-stadernas-gator/

Our preliminary observation that the multifunctionality of streets has not been addressed adequately in scientific literature is confirmed. The notion of street multifunctionality seems to be rather new and although it is sometimes implied or presented as a general vision for future streets, it has not been systematically studied. Only in the paper abstracts discussing green streets, the technical, ecological, social and economic functions are studied and discussed in combination.

The abstract classification confirms the initial indication that the different street functions are addressed separately in literature (figure 3). The technical function appears dominant in the selected abstracts and represents 27% of all abstracts. This can be explained by the numerous studies focusing on street elements, such as smart street lighting and smart materials. Without these studies, the technical function would drop from 27% to 12%. The ecological and social function are also relatively often addressed in literature, while the economic function remains understudied in comparison and is mostly represented by studies on UK's High streets. The traffic function is mostly discussed in papers on multimodality.

In relation to the type of study, after the abstract sorting, we identify two main clusters of papers. The first

Figure 4.
Types of studies (left) and functions (effects) in focus in the empirical studies (right).



group focuses on street design, usually referring to case studies (385 papers) and the second cluster of papers covers empirical studies focusing on streets' spatial, environmental and societal effects (311 papers). Out of these 696 papers, 106 are overlapping, being empirical studies that refer to specific street design case studies or before-and-after empirical studies of a street retrofit (figure 3). A third cluster of 244 papers focuses on smart street elements (e.g. street lighting). Further, 123 papers refer to related policies (e.g. Complete streets, Safe roads to schools); 78 refer to or introduce indices and scores (e.g. Smart Street Walk Score, Pedestrian Safety Index, Liveability Index); 69 refer to future mobility systems (self-driving vehicles, VANET); while the rest (68 papers) are general texts discussing ideas, visions and principles (figure 4).

Of all the empirical studies (311 papers), the social function is most often studied where Health related to physical activity (e.g. active mobility, walkability, bikeability) (88 papers) and Safety (64) dominate, followed by Liveability (28) and Security (14) (figure 4). The Ecologic function is also quite highly represented including Microclimate (37 papers) and Air-pollution (36). The Economic function is rather unexplored as already mentioned, and the economic effects of streets as land prices, housing prices and business developments are referred to in only 10 papers.

Almost all geographic regions are represented, from USA (26%), Canada (12%), to different European countries (21%), China, Japan, India and other Asian countries (29%), Australia and New Zealand (8%), South American (2%) and African countries (3%). In the empirical studies a lot of attention is given to the different age groups, from small children, to youth, young adults, adults, middle-aged and elderly. Gender, physical disabilities, economic status and ethnicity are represented but to a much lesser degree.

After this general survey of the field which included all 1172 abstracts, the next chapters focus on the empirical studies. The thematic reviews based on the empirical full paper reading aim at identifying the physical factors which have been empirically proven to support not only the separate street functions, but especially street multifunctionality. The findings of these thematic reviews are presented in the following chapters. First, we discuss the physical factors which promote liveability and safety, two aspects of the social function that are interrelated but often conflicting. Second, we discuss the green street review results where besides the evidence on the environmental benefits of green streets, also their social and economic benefits will be discussed.

The last chapter of this report focuses on linking the results of the thematic reviews to the discussion of the Street Function Index (Gatufunktionsindex)

3. STREETS SUPPORTING LIVEABILITY AND TRAFFIC SAFETY

As stated, a central aim of the review is to identify the physical factors which have been empirically proven to support not only separate street functions, but especially street multifunctionality. Thus, particular focus is placed on physical factors that support more than one street function.

This chapter focuses on the empirical papers that study liveability and traffic safety, two important aspects of the social function, interrelating but often conflicting. Such focused thematic reviews that extract significant physical factors from empirical studies, provide valuable input for the design principles and guidelines of multifunctional streets and for the Street Function Index.

Supporting liveability in multifunctional streets

For liveability, out of the 28 selected papers, 4 full texts were found irrelevant, 2 were missing and 2 did not study specific physical factors. For each of the remaining 20 papers included in the thematic review, the physical factors that were found to improve liveability are recorded and grouped. Next, the papers where each factor was mentioned in support of liveability are counted to be able to rant the factors based on this count. The papers mention in total 113 factors that are reduced to 45 unique factors related to liveability (Stavroulaki and Berghauser Pont, 2019b).

Stavroulaki and Berghauser Pont (2019b) https://smartagator.wordpress.com/2019/11/06/utformning-som-stodjer-gators-livskvalitet-liveability/

Liveability is strongly related to the presence of people on the streets as much and for as long as possible, engaging in different activities such as walking, sitting, dining, biking, playing, shopping etc. To support this this, factors related to connectivity and accessibility to diverse services and uses, safety, attractiveness and sense of place are important as these increase co-presence. Besides these factors that promote many people to be present, equal access to all people, no matter the age or mobility impairments (e.g. people in wheelchairs, visually impaired, people with strollers, elderly, children, injured) is high on the list of necessary factors for achieving liveability. What is also discussed frequently is the importance of the perception of liveability from the people living and using the streets. In that sense, qualities such as safety have a two-way relationship with liveability, where safety increases the perception of liveability and liveability in the meaning of liveliness and 24/7 use of the street contributes to the sense of safety.

The 45 unique physical factors that arguably support liveability based on the 20 empirical studies and reviews can be divided in two distinct groups. The first group include factors that go beyond the components of the individual street and express the importance of the location of the street in its larger context. In this group, the factor most often mentioned as important is accessibility to services, followed by network connectivity measured as high intersection density or small blocks. Public transport is mentioned as the third most important contextual factor. The following five contextual factors are identified (in brackets, the number of papers that mention the factor; factors only mentioned in one paper are not included):

- Accessibility to services within walking distance (e.g. 0,8km from each street segment). Services include community services, educational institutes, recreational areas, open and green areas, food shops, retail, cultural centres, major medical care and health centres (14)
- Network connectivity, small blocks, high intersection density (9)
- Accessibility to public transport (7)
- Absence of physical and unattractive barriers in the vicinity, such as high-traffic and low-design arterial roads, sketchy non-vibrant arterials etc (4)
- Built density in relation to population, both residential and working (2)

The second group of physical factors are street related and describe the more local conditions that promote liveability. The list of these local factors is long, and we therefore present them in five distinct themes:

- Features related to traffic volume and speed such as traffic calming features for low vehicular speed (6) and reduction and narrowing of vehicular lanes (3). It should be noted that three empirical studies, two on arterial roads, support that high-traffic and liveability are not mutually exclusive, that high-traf-

fic flow can be related to vibrancy and that low-traffic flows does not guarantee higher liveability, and can create problems (e.g. crime, vandalisms) if other important factors are missing.
- Street design features such as greenery (12), wide sidewalks and pavement quality (10), mobility impairments (e.g. ramps, tactile pavement) (10), presence of benches and sitting areas (5), buffer with vehicular lanes (on street parking, landscape etc) (4), cleanliness and waste management (4) and on-street parking (6). For the latter, the results are inconclusive, sometimes it is considered positive (4) and sometimes negative (2). There are other factors mentioned, but in less than four papers such as lighting (3), shading (2), attractive features, such as water (2) and dining areas (related to restaurants, cafes etc) (2).
- Features promoting non-motorised and active travel and when a trade-off is needed because of limited space, it always favours the pedestrian. The factors mentioned in at least two papers are presence of pedestrian paths (13), public transport stops and lanes (7) and bike lanes (4), semi-pedestrian streets with access to emergency vehicles (2) and shared space (2).
- Ground-floor pedestrian oriented uses (retail, restaurants, cafes, public services etc) (4) and mixed land-use (3).
- Building morphology including building diversity (e.g. age, style, scale) (4), scale of buildings (2), street framing, visual enclosure, setbacks (2), facades, building codes (2) and emphasis on historical or iconic buildings and landmarks (2).
- Safe crossings, promoted through frequent pedestrian crossings (5), median for pedestrians for wide streets (2) and intersections as shared space, where awareness of all modes of travel creates slowing down and safe crossing (2).

On street parking may need some more explanation as it is often debated. Papers on liveability state the benefits of on-street parking, because of its relation to pedestrian safety by creating a buffer between cars and vulnerable groups. But on the other hand, it can decrease mutual visibility between drivers and pedestrians-cyclists that contributes to increased risks for crashes when crossing the street (Congiu et al. 2019; Fauzi and Aditianata 2018; Hanson et al. 2013). Therefore, it might be recommendable to choose other features that create a buffer between cars and pedestrians-cyclists that are considered to improve safety of vulnerable users, but do not create obstacles to their mutual visibility.

Figure 5.
Ranking of physical factors that support liveability based on the amount of empirical papers that have found them significant.

Besides the argument of safety, other papers on liveability show that in general inadequate parking space is considered a negative factor for the attractiveness and liveability of an area, as it results in double parking on the streets, congestion, unsafety etc. (Lethco,et al. 2009; Mahmoudi et al. 2015). Also, from the papers on economy, easiness to find parking space is one of the factors that interviewed people mention as reason to shop in large shopping malls, rather than shopping streets in the city (Reimers 2013).

Figure 5 shows the ranking of these physical factors that are used in more than 4 papers, both related to context and to individual streets. The ranking is based only on the amount of papers that have studied each factor and have found it relevant or significant for liveability. It does not take into account the relative importance (e.g. statistical correlation) of each factor in comparison to other factors, as the variables that are compared in each paper vary, and so does the dependent variable and the method of assessment, correlation or association.

Supporting traffic safety in multifunctional streets

In similar ways as described for liveability, for traffic safety, 64 full papers were assessed but 26 did not refer to physical factors and were therefore excluded (Stavroulaki and Berghauser Pont 2020a). For each of the remaining 38 papers included in the focused review, the physical factors that were found to improve safety are recorded and grouped. The papers often focus on different road users and study either pedestrian, cyclist or driver safety. We will therefore report these findings separately. Furthermore, the indicator of safety, or more precisely, of unsafety, also varies. A measure of the unsafety of a street can be the number of vehicular crashes, the severity of crashes or the number of fatalities in each street. Apart from vehicle-to-vehicle crashes, vehicle-to-pedestrian or to-bike crashes and bike-to-pedestrian crashes are used to measure pedestrian and cyclists' unsafety. Another important aspect that is studied is the perception of safety especially from the vulnerable users' point of view (e.g. Lawson et al. 2013).

It should be noted that the context of this systematic review is the multifunctionality of streets and because of this, it includes only a very limited share of papers on traffic and road safety. In other words, papers included in this report are the ones that study safety in streets that are of multifunctional and/or multimodal character.

For the same reason and as expected, many studies place particular interest on the potential conflicts that emerge from the meeting of different street users (drivers, pedestrians, cyclists); a meeting that is promoted by the concepts of shared space, multimodality and multifunctionality. What emerges is the tension between the desire to increase the active travel modes, like walking and biking, and the overall liveliness of the streets, and at the same time ensure the safety of the co-present street users; a safety that is arguably threatened by their exposure to each other (e.g. Islam et al. 2014; Larson et al. 2013; Mac Leod et al. 2018). From a traffic safety perspective, the potential meetings between vehicles, bikes and pedestrians affect the chances of a crash occurring negatively. A case in point is that two factors that are reported to relate to vehicle-pedestrian crashes in Complete streets are the actual pedestrian volume and the level of exposure to vehicles (Mac Leod et al. 2018).

However, the exclusion of vehicles from an individual street is not promoted as a universal remedy to increase safety, because that might put pressure on other streets and in fact increase the levels of accidents elsewhere. Throughout the selected papers there is an effort to take a more holistic approach to the problem that not only promotes safety from one perspective and for one street, but from the perspective of achieving both liveability and safety in the whole urban context. The underlying challenge and question posed is: How can we promote co-presence of the different street users and at the same time eliminate the situations of potentially dangerous conflicts that can lead to crashes?

The papers presented 57 physical factors that we reduced to 28 unique factors related to safety. There are also important non-physical factors highlighted in the papers (such as alcohol and substance use while driving, seatbelt use, weather, age etc), but we do not report on those.

Stavroulaki and Berghauser Pont (2020a) https://smartagator.wordpress.com/2020/03/17/vad-sager-forskningen-om-gators-trafiksakerhet/

Based on the empirical studies, physical factors can promote or hinder all three aspects of traffic safety; pedestrian safety, cyclist's safety and driver's safety. Like the overview given for liveability, the factors can be divided in two main groups. 21 factors are related to the physical space of the individual street and 5 factors are related to the context or the network of streets.

Low vehicular speed is the most decisive parameter of traffic safety, and there is a number of physical factors that have been proven to improve traffic safety by way of reducing vehicular speed. These are documented below (in brackets, the number of papers that mention the factor; factors only mentioned in one paper are not included):

- Higher network connectivity, higher intersection density, small blocks (5). It should be noted that besides these five papers that highlight the importance of small blocks, two other papers give contrary results; one because of many hazardous intersections.
- Low number of lanes, but should be more than one (4)
- Fused grids, no vehicular through traffic (3)
- Traffic calming features (3)
- Narrow lanes (2), 9ft is the proposed width
- Street lighting (2)
- Proximity to city centre (2). It should be noted that proximity to the city centre decreases the severity and not the number of crashes. Furthermore, one paper gave conflicting results, making this a less reliable factor in relation to safety.
- More commercial uses (2), but again also one paper with conflicting findings

Besides low vehicular speed, factors that significantly correlate to pedestrian and cyclists' safety are:

- Lower traffic volume (5) (to be noted that traffic volume might increase the number of crashes but decreases the severity because it decreases speed)
- Short crossing distance for pedestrians and cyclists (e.g. with curb extension or median (5)
- Mutual visibility of drivers and pedestrians or cyclists (5), mainly related to absence of buffers such as on-street parking (4) and barriers (3)
- Separate one-way bike lanes (4)
- Sidewalks on both sides (4)
- Crosswalks (3)
- Intersection treatment such as clearance in unsignalized intersections of 2-5m (3)
- Continuity and connectivity of bike lanes (2)
- Absence of bus stops, because they are related to complex traffic environment (2)

As in the case of liveability, the scoring is based only on the number of papers that have studied each factor and have found it significantly correlated to traffic safety. It does not take into account the relative importance (e.g. statistical correlation) of each factor in comparison to other factors that are found, as the variables that are compared in each paper vary, and so does the dependent variable and the method of assessment, correlation or association.

Traffic safety focusing on vulnerable users

Focusing on the vulnerable users, figure 6 on the next page shows three main categories of the physical factors that have been shown to improve pedestrian and cyclist safety most. The first category is related to the main cause of unsafety, which is by far the vehicular speed. Although vehicular speed is in particular focus, some studies point to bicycle speed as a rising concern as well (e.g. Essa et al. 2018). What is empirically confirmed in most papers is that the lowering of vehicular speed, either by speed limits or by traffic calming features, greatly improves all measures of traffic safety (number and severity of crashes and fatalities). Other factors in this category, such as high network connectivity or low number of lanes, that are also found to improve safety, do so because they are associated with lower speeds.

Figure 6.
Three main categories and ranking of physical factors that support safety based on the number of empirical papers that have found them significant.

The second category includes factors which aim to limit the exposure of vulnerable users to vehicles by increasing their temporal (i.e. short crossing distance) or physical separation (e.g. low traffic volume, sidewalks and separate bike lanes, buffers and barriers, narrow car lanes). The third category is less studied but is still identifiable as a separate theme in the papers. The physical factors of this category are not related to the separation of the different users, but to their safe interaction (e.g. mutual awareness and visibility of road users, legible intersections, crosswalks).

Interestingly, the thematic review not only extracts the significant physical factors for traffic safety, but also highlights their overlaps and conflicts, something particularly important for their practical application in design. Some factors improve traffic safety for all users, while others are conflicting. For instance, the use of roundabouts instead of regular intersections has been proven to reduce car accidents and improve the safety of drivers, but by creating illegible crossings for pedestrians can hinder their safety (Marshal, 2018). Some factors affect the number of crashes, while others the severity of injuries, the number of fatalities or the number of potential conflicts. A case in point is the proximity to the city centre and traffic volume. These might be related to increased number of crashes, but their severity and number of fatalities is decreased because they are associated with lower vehicular speed (Marshall and Garrick 2011). Other factors improve all indicators of traffic safety, such as network connectivity (Guo et al., 2015, Marshall and Garrick 2011, Marshall and Garrick 2010, Mecredy at al. 2012).

Often the empirical results are conflicting and thus inconclusive, such as the impact of the presence of buffers between vehicle lanes and sidewalks (e.g. on-street parking). Such buffers might protect pedestrians by physically separating them (e.g. Hanson et al 2013) but have been reported to increase crashes in uncontrolled crossings, because they decrease mutual visibility and awareness between drivers and pedestrians (e.g. Congiu et al. 2019). Another case in point is the one-way streets that have been reported to relate to both less (Islam et al 2014) and more crashes (Congiu et al. 2018). One-way streets are associated with less crashes, but only when they have low car traffic (volume and speed). One-way multi-lane streets, on the other hand, are associated with more collisions, higher crime (robberies etc.) and lower property values in comparison to their two-way counterparts (Riggs and Gilderbloom 2016, 2017).

The three identifiable categories of physical factors that are found to improve traffic safety can also be described as the three main strategies used to tackle the problem. Currently, lowering speed limits and separating users and different transport modes spatially (with designated or separate lanes with barriers and buffers) or temporally (with traffic lights and signals) (e.g. Islam et al 2014; Mac Leod et al 2018; Lawson et al 2013) are the main strategies used. Most multimodal streets today implement these strategies. The third less studied and less used strategy of safe user interaction is related to the notion of "shared space". However, this strategy is often necessary as the limited physical space of the street requires that different modes and users share the same lanes, as for example pedestrians and cyclists; a necessity that increases as new forms of mobility and shared mobility are introduced demanding a renegotiation of street space (e.g. e-scooters). Moreover, looking at the conflicts that emerge between the safety factors that improve the safety of drivers on the one hand and of vulnerable users on the other (e.g. the case of roundabouts and illegible intersections), we see that separating and sub-optimizing for one mode might hinder the safety of another. We therefore want to highlight recent studies that explore the notion of safe interaction in shared space as an alternative to the mainstream approach to multimodality by separating users and modes.

Shared space and traffic safety

Out of the 12 full texts that deal with the notion of traffic safety in shared space, 7 focus on modelling user behaviour and interaction (e.g Pascucci et al 2015; Obeidat et al 2017; Rinke et al 2017; Obeid et al 2017; Wang et al 2012; Kaparias et al 2015) and 5 are empirical studies (Essa et al 2018; Pecchini och Giuliani 2015; Piatkowski et al 2017; Curl et al 2015; Danaf et al 2018). The high share of papers that focus on sophisticated modelling and simulation of user behaviour especially in conflict avoidance, comes from the understanding that in shared space environments the movements of road users are not regulated by traffic rules, but are the result of spontaneous interaction between people, who negotiate the priority according to social rules, such as eye contact or courtesy (e.g. Rinke et al 2017). Their interaction is the result of a complex human decision-making process, thus requiring a sophisticated modelling approach. What is more, many more types of users and groups of users need to be taken into account such as pedestrians, cyclists, joggers, pedestrians with stroller or wheelchair, pedestrians pulling or pushing luggage, pedestrians with hearing impairment, pedestrians with visual impairment, elderly etc, because of their different understanding of the environment, different behaviour in conflict avoidance, different speed or easiness to manoeuvre (Essa et al 2018). Group dynamics are also in play and are considered in modelling user interaction in shared environments. For example, a pair of pedestrians behaves differently than a group of three or more pedestrians when encountering and interacting with other road users. However, what is common in all studies is the assumption of very low speed limits in such shared environments. Although, the exclusion of a specific travel mode, such as cars, is not explicit or mandatory in a shared space, what is clear is the need that all users travel in very low speeds (Essa et al 2018, Rinke et al 2017, Kaparias et al 2015, Danaf et al 2018).

Speed is presented again as the most decisive factor for safety; lower speed is not only a strategy of improving traffic safety in its own right but is also the perquisite of safe user interaction in shared space environments. What is proposed is that the potential conflicts that arise when streets become more and more multimodal and multifunctional can be counteracted by low speeds of movement, complemented by legibility of the environment and mutual visibility and awareness of users. In this view, the role of context is of utmost importance, as it can help identify roads, streets and locations that could function as efficiently with lower speed limits from those that require higher speeds because of their place in the overall street network and transport system of the whole city.

Combining liveability and traffic safety: overlaps and conflicts

The parallel thematic reviews of liveability and traffic safety are particularly interesting as they bring forward the potentials and at the same time challenges of the multifunctionality concept and its potential practical application in future street designs and retrofits. Multifunctionality implies the combination of street functions, which are nonetheless often conflicting. A case in point is the liveability-safety combination. Although traffic safety and the perception of traffic safety is a necessary factor for achieving liveability, liveable streets also require 24/7 liveliness of the street, active travel, utilitarian and recreational walking and biking, multimodality, diversity of uses, sharing of space, inclusion and meeting of different users, all of which place potential threats to traffic safety. From a traffic engineering perspective, traffic safety is related to the separation of users and modes of travel (whether temporal or spatial), rather than their combination. Even the notion of multimodality that is closely related to street liveability, puts pressure on traditional approaches to traffic safety, let alone the multifunctionality concept which goes even further to include a multitude of functions than mere transport (e.g. seating, resting, shopping, socializing, outdoor eating, strolling, running, recreational walking and biking, meeting, exercising).

As the traffic safety review showed, a main strategy which promotes safety, is the separation of street users, temporal or spatial, and their limited exposure to each other (Islam et al. 2014). What emerges is the tension between the desire to increase the active travel modes, like walking and biking, and the overall liveliness of the streets and at the same time ensure the safety of the co-present street users; a safety that is arguably threatened by their exposure to each other.

The underlining challenge and question is therefore: How can we have street sharing and co-presence of the different street users and at the same time eliminate the situations of potentially dangerous conflicts that can lead to traffic accidents?

On the other hand, the parallel review of empirical papers on liveability and safety also highlighted physical factors which support both aspects and thus have an additive positive effect for street multifunctionality. Cases in point are network connectivity, physical factors that reduce car speeds, wide sidewalks, separate bike lanes, frequent and safe pedestrian crossings, narrow car lanes, short crossing distances and presence of commercial and pedestrian oriented uses.

The latter supports not only the social function of the street with outdoor eating, strolling or shopping, it also has been proven to increase walkability, and supports the economic function. The same goes for network connectivity which, as the empirical studies showed (Guo et al. 2015; Marshall and Garrick 2010,2011; Mecredy et al. 2012) , improves both walkability, liveability and traffic safety and has also been associated with the economic development of the street, especially with pedestrian oriented uses (e.g. food, retail) (Islam et al 2014; Mac Leod et al. 2018; Lawson et al. 2013). This idea can be further extended outside the social, economic and traffic function to include for example street greenery that is not only important for street liveability but a necessary element and a carrier of the ecological function with positive effects on microclimate, tackling air-pollution and supporting urban floras and faunas. This will be discussed in the next chapter.

4. GREEN STREETS SUPPORTING MULTIFUNCTIONALITY

Streets can offer ecological benefits in their own right, with street greenery and stormwater management features, but they can also boost the potential environmental benefits to their urban context, by connecting urban green patches, by offering accessibility to urban green areas or by being ventilation corridors that clean the air and reduce urban heat island effects and improve the microclimate in general. Apart from the environmental value, these effects can also bring social and economic benefits. For instance, exposure to green in streets has shown to increase the perceived liveability, the attractiveness of an area as is shown in the willingness to pay more for housing in streets with more access to green. Furthermore, it can support mental health, and also benefit physical health by improving air-quality and triggering more physical activity such as walking.

This chapter focuses on the ecologic street function. It reviews the relevant empirical studies and seeks for evidence on the environmental benefits of green streets. It also reviews evidence on the further gains of these types of streets that are of social or economic character. We identify the different types of street greenery and street water management infrastructure that are the most impactful and are associated with more than one positive effect. Such factors can support more than one street function, generating the synergies that are an essential part of the multifunctional street concept.

Following the method of the overall systematic review, 81 abstracts were sorted as relevant. After reading the full texts, 41 papers were excluded from the final report, because they didn't provide empirical data, didn't focus on street greenery, or studied the negative environmental impacts of highways and road traffic, which is out of the scope of the Smart Street project.

From the remaining 40 full papers, 33 empirical studies focus on green streets. Most papers focus on street greenery, but we also include papers focusing on water management systems (3 papers), green buildings along the street (2 papers), private gardens facing the street (2 papers) and green vacant lots along the street (1 paper). These features are regarded to be an integral part of the streetscape and canopy and are therefore included in the report. Finally, 2 papers do not test the impact of green streets locally, but their benefits in creating green connectivity. To be noted is that because the context of this systematic review is the multifunctionality of streets, it includes only a very limited share of papers about urban green and green corridors. In other words, papers included in this study are the ones that study greenery in streets that are of multifunctional and/or multimodal character.

The studies in the 40 papers can be subdivided in two groups, where the first discusses direct environmental effects (23 papers) and the second studies indirect social and economic effects of greenery (14 and 3 papers respectively). In other words, although the focus is on the environmental benefits of green streets, the factors that contribute to this very often, also deliver important social and economic gains. The direct environmental effects cover aspects such as microclimate (9 papers), biodiversity (6), air pollution (5), and storm water management and flooding (3). The indirect social and economic effects cover the impact of greenery on health by way of improving air-quality (i.e. birth weight, birth outcomes; 2 papers), walking and physical activity (3 papers), mental health (i.e. geriatric depression, 1 paper), liveability and the perception of liveability (5 papers) and security from crime and the perception of security (3 papers). Lastly, 3 papers measure the economic effects of green streets, both directly, by raising property values and indirectly, by increasing attractiveness and willingness to pay.

Thus, green streets show high multifunctionality potential as they influence many environmental, social and economic functions, from air-pollution to land prices (Stavroulaki and Berghauser Pont 2020b). In figure 7 on the next page, an overview of these categories addressed in the papers is given. It should be noted that although green streets can have multidimensional benefits and are highly supportive to the concept of the multifunctional street, under certain conditions some types of street greenery can also have negative effects. This will be discussed in detail in the following sections.

Stavroulaki and Berghauser Pont (2020b) https://smartagator.wordpress.com/2020/06/23/gronskans-betydelse-for-mangfunktionella-gator/

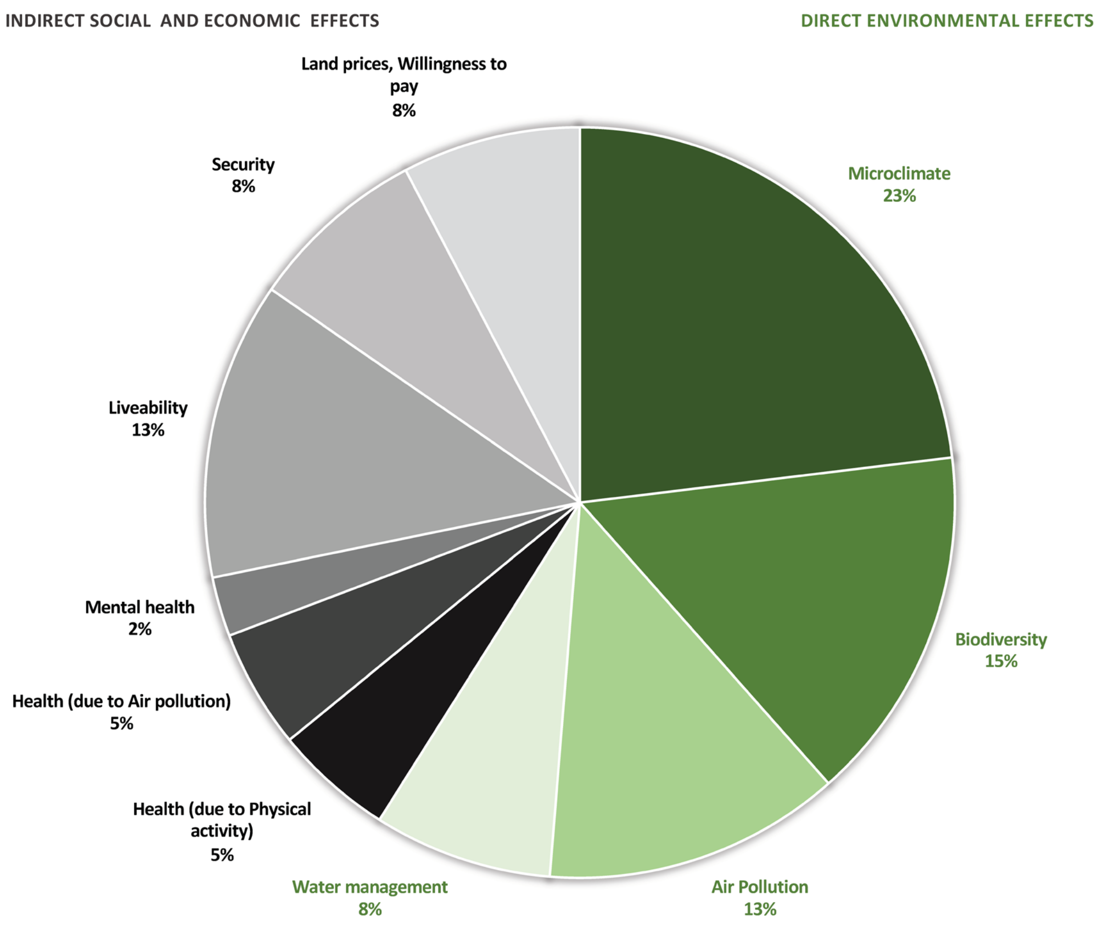


Figure 7.
Share of direct environmental effects and indirect social and economic effects studied in the 40 empirical studies.

Ecologic, social and economic benefits of green streets

The review shows that green streets support many functions: they reduce flooding hazards (Jose et al. 2015, Lin et al. 2018), promote health by way of increasing physical activity and attracting walking (Adkins et al. 2012, Sarkar et al. 2015, Nguyen 2018) and improve mental health (i.e. geriatric depression) (Helbich 2019). Streets with high green coverage are also associated with less adverse birth outcomes (Abelt and Mc Lafferty 2017) and higher birth weight especially in highly dense areas (Cusack et al. 2017). Furthermore, green streets promote liveability and increase residential satisfaction (Kim et al 2017b; Mahmudi et al. 2015; Fauzi et al. 2018; Norouzian-Maleki 2018; Curl et al. 2015) as well as house prices and residential estate value (Zhang and Dong 2018; Netutsil et al. 2014). Finally, a study reported that streets with green vacant lots had less assaults and violent crimes than streets with unplanted lots. (Heinze et al. 2018).

Green streets do not only support local ecologic functions, but also increase green connectivity and thus create larger continues green areas that, in turn, positively supports biodiversity (e.g. Vergnes et al. 2012; Maruyama 2019) and microclimate (e.g. Jiang et al. 2018). Furthermore, high percentage of green in an area can decrease noise pollution (e.g. Margaritis and Kang 2016; Liu et al. 2013) and air-pollution (e.g. Cusack et al. 2017; Abelt and Mc Lafferty 2017). High exposure to green can be therapeutic for high stress levels (Vaeztavakoli et al. 2018; Marselle et al. 2013), while higher proximity and accessibility to green is indirectly related to the liveability and attractiveness of an area (e.g. Norouzian-Maleki 2018; Mao et al. 2015).

Potential conflicts related to street greenery

While there are many studies which report positive effects of green streets, other studies point to potentially negative or conflicting effects, especially when it comes to air quality, microclimate and biodiversity. Whether effects are positive or negative depends on the type and layout of street greenery such as the choice between trees or shrubs, evergreen or deciduous trees and tree distance (e.g. Kurppa et al 2018; Jin et al. 2014; Mori et al. 2018). Other important factors are street orientation (e.g. Huang et al. 2017; Morille et al. 2016), street canopy (e.g. Kim et al 2017; Jin et al. 2014; Mori et al 2018), building morphology (e.g. Kurpa et al. 2018), and of course the climate zone the street is located (e.g. Huang et al. 2017; Jiang et al. 2018; Morille et al. 2017), the local weather conditions (e.g. Tsiros 2017) and the season (e.g. Jiang et al. 2018; Shojaei et al. 2017).

It is therefore important to in detail investigate the different types and factors of street greenery and blue infrastructure and their reported positive and negative effects. Table 1 classifies the types of street greenery studied in the empirical papers, mostly trees (22 papers) and shrubs (3 papers). 8 papers do not specify a type, but rather refer generally to street vegetation. Table 2 focuses on the specific factors studied, such as tree height, tree canopy, plant species, tree and shrub layout, the number or tree rows and shrub layers, the tree distance or their placement in relation to the street width and the buildings. In both tables, a plus (+) represents a consistent positive impact, while a plus and minus (+-) indicates that the type or factor has a positive impact, but under certain conditions it might also have a negative one. A minus (-) indicates a reported negative impact of this factor.

Table 1.
Overview of papers per green type and per category. Plus (+) shows positive effects and minus (-) shows potential negative effects, plus and minus (+-) indicates that the type or factor has a positive impact, but under certain conditions it might also have a negative one.

		CATEGORIES	AIR POLLUTION	MICROCLIMATE	BIODIVERSITY	RUNOFF CONTROL-WATER MANAGEMENT	HEALTH - PHYSICAL ACTIVITY	HEALTH - AIR POLLUTION	MENTAL HEALTH	LIVEABILITY	SECURITY / PERCEPTION OF SECURITY	ECONOMY
	PAPERS		*5 PAPERS*	*9 PAPERS*	*6 PAPERS*	*3 PAPERS*	*3 PAPERS*	*2 PAPERS*	*1 PAPER*	*5 PAPERS*	*3 PAPERS*	*3 PAPERS*
GREEN STREET AND STREETSCAPE	40	10	+ -	+	+ -	+	+	+	+	+	+ -	+

STREET GREEN TYPES	PAPERS	CATEGORIES	AIR POLLUTION	MICROCLIMATE	BIODIVERSITY	RUNOFF CONTROL-WATER MANAGEMENT	HEALTH - PHYSICAL ACTIVITY	HEALTH - AIR POLLUTION	MENTAL HEALTH	LIVEABILITY	SECURITY	ECONOMY
TREES	22	9	+ -	+	+ -	+	+	+		+	+ -	+
SHRUBS	3	2	+								+ -	
PLANTERS	2	1								+		
WATER MANAGEMENT SYSTEMS	2	2				+	+					
MEDIAN, ROAD-SIDE VEGETATION	2	1			+							
GENERAL STREET VEGETATION	8	5		+	+		+		+	+		
RESIDENTIAL PRIVATE GARDENS	2	2					+			+		
GREEN BUILDINGS	2	2		+						+		
GREEN VACANT LOTS	1	1									+	

Table 2.
Overview of papers per factor related to trees and shrubs.

TREES AND SHRUBS FACTORS	PAPERS	CATEGORIES-FUNCTIONS	AIR POLLUTION	MICROCLIMATE	BIODIVERSITY	SECURITY	ECONOMY
TREE HEIGHT	4	1		+			
LEAF DENSITY (LAI_LEAF AREA INDEX)	4	2	+ -	+			
TREE CANOPY AREA	7	4	+ -	+			+
NUMBER OF TREE ROWS	1	1	+				
TREE PLACEMENT	2	2		+			+
TREE PROXIMITY (SMALL TREE DISTANCE)	3	2	+ -	+			
TREE CLOSENESS TO BUILDINGS	2	2		+			
PLANT SPECIES	2	2	+		+		
SHRUB HEIGHT	1	1				-	
SHRUB COVERAGE	1	1	+			-	
SHRUB LEAF DENSITY	1	1	+			-	
NUMBER OF SHRUB LAYERS	1	1	+				

Starting with air-pollution, trees are associated with decreased air-quality in street canopies, especially with a low width/height ratio, because in such streets, they can block wind and hinder the natural street ventilation. The problem increases at the lower parts of the street canopy, that is, close to the level of pedestrians (Kurppa et al 2018, Jin et al. 2014). The level of the negative impact depends on street orientation in relation to the wind direction, the urban block structure, the season and the climate zone. For example, Jin et al. (2014) suggest that deciduous trees s or trees with low leaf density should be used instead of evergreen tree in a city such as Shanghai because they allow the wind to run through during winter, the most polluted season in Shanghai. Kim et al. (2017) suggest high tree distance in order to avoid blocking the street ventilation and Matsunaga et al. (2017) point to the use of specific tree species in street planting. Kurpa et al. (2018) found in a study in Helsinki that the ventilation problem increases when the longer side of the urban block is parallel to the street, again considering the local weather conditions and wind orientation. When air-quality is the issue, shrubs are often suggested as a more appropriate type than trees, because they can filter traffic-related pollutants that concentrate on the lower levels of the street canopy, without blocking wind and street ventilation.

Different from what is recommended for narrow street canopies, in open roads with high vehicular traffic, roadside trees with high density (close to each other, high leaf density, large coverage) can help in efficiently filtering traffic-related pollutants. There, a combination of trees and shrubs can effectively improve air quality (Mori et al 2018, Kim et al 2017).

The effects of street greenery, mainly street trees, on microclimate are always positive (Huang et al. 2017; Jiang et al. 2018; Morille et al. 2017; Yang et al. 2018; Shojaei et al. 2017; Sanusi et al. 2016;Wang et al. 2018; Tsiros 2010; Klemm et al. 2015). However, the level of positive influence always depends on the climate zone and season (Jiang et al. 2018; Shojaei et al. 2017; Song and Wang 2016), time of day (Sanusi et al. 2016), street orientation (Huang et al. 2017; Morille et al. 2016; Yang et al. 2018; Sanusi et al. 2016) and urban density (Tsiros 2019; Wang et al. 2018). In general, the benefits are higher in warmer conditions. The environmental gains are multiplied also because lowering street temperature decreases the cooling energy demand on buildings (Huang et al. 2017; Morille et al. 2016; Song and Wang 2016).

There is thus an emerging conflict that needs to be addressed, between the impact of trees on air-quality in street canopies and their impact on microclimate. High tree density - as expressed by high leaf density , large tree canopies and small tree distance - is a beneficial factor for reducing street temperature (e.g. Huang et al. 2017; Jiang et al. 2018; Morille et al. 2017; Sanusi et al. 2016; Wang et al. 2018; Klemm et al. 2015). It also provides shading (e.g. Tsiros 2010; Wang et al. 2013) and reduces the cooling energy demand of the adjacent buildings (e.g. Huang et al. 2017; Morille et al. 2016). However, as already described, high tree density can block the wind and hinder street ventilation, which in turn has negative effects on air-quality.

Biodiversity is another category that is not necessarily supported by street greenery. Although street green supports urban habitats (Pecarevic et al. 2010; Ranta et al. 2015; Vergnes et al. 2012; Maruyama 2019), these often show a high degree of homogenisation, higher than other types of urban habitats, such as parks or residential green areas (Lososova et al. 2011 2012). The relevant studies point to the importance of the selection of appropriate plant species for each context in order to create habitats for a more diverse flora and fauna (Ranta et al. 2015; Marouyama 2019; Lososova et al. 2011, 2012).

From the studied indirect social effects, a potentially negative impact of street greenery was reported in relation to the perception of security (Ozhanci 2014; Cinar and Cubukcu 2012). Planting can have both positive and negative results depending on the details of implementation. Rows of street trees creating strong vertical and horizontal axes have a positive impact because they increase orientation and control over the urban environment (Ozhanci 2014). On the contrary, high and dense shrubs that block visibility can have the opposite effect (Ozhanci 2014; Cinar and Cubukcu 2012). Thus, in order to promote the feeling of security, the layout and planting density should create a legible and transparent environment for walking that improves orientation and ensures the visual overview of the urban environment. Another conflict emerges at this point between the improvement of air-quality in the street and the sense of security. It was shown that dense shrubs in streets are beneficial for improving air-quality, since they filter traffic-related pollutants (Mori et al 2018; Kim et al 2017). However, dense shrubs, especially if they are also high, might have a negative impact on the perception of security.

Multifunctional green streets
Summarizing, we can conclude that street greenery has direct environmental impact on air-quality, biodiversity and microclimate. Storm water management systems of green streets decrease flooding hazards. Green streets have indirect social effects by improving health, both by improving air-quality and by attracting more walking and physical activity. They also improve mental health, liveability and the sense of security. Finally, they bring economic benefits both directly, by raising property values and indirectly, by way of increasing attractiveness and willingness to pay.

By far the most influential and multifunctional street greenery type is street trees, followed by shrubs. However, both are also associated with possible negative effects, depending on their placement. Design factors to take into account when designing green streets are street orientation, street width/height ratio, urban block morphology, the climate zone and the local weather conditions. For example, in open streets, trees and shrubs can filter traffic-related pollutants and improve air-quality. However, in narrow street canopies (with low width/height ratio), dense and large evergreen trees in small distances can block wind and hinder street ventilation, which has negative effects on air-quality. At the same time, tree density is the most influential factor in improving the microclimate, by decreasing street temperature, especially in warm climate zones. A conflict between two important ecologic street functions thus emerges, that needs to be addressed with appropriate design and selection of plant species. The selection of tree species is also key to support biodiversity and reduce the species homogenisation, that is often observed in green streets.

Shrubs, on the other hand, are performing better than trees regarding air-quality, since they filter traffic-related pollutants, but do not block wind. However, they do not affect microclimate to the same extend. In addition, dense and tall shrubs were found to decrease the sense of security by limiting visual overview and hindering the pedestrian's sense of control over the environment. The combined impact of trees and shrubs are also documented, for example, on biodiversity and on air-quality, where studies advocate for street greenery combining the two and other types of green (e.g. planters).

When the aim is street multifunctionality, it is key to highlight both the overlaps and positive synergies, as well as the conflicts between the different street functions. Even when the choice seems too detailed, as for example the selection of tree species or their exact placement and spacing, this report shows that it can be a decisive one. It became clear that the presence of street greenery alone does not guaranty positive environmental effects; contextual factors, such as the climate zone, the street orientation or the street canopy width/height ratio, need to be taken into account in order to assess their impact. That said, streets trees when selected and placed appropriately can have multiple benefits and support many important street functions.

5. STREET FUNCTION INDEX

The results of the thematic reviews presented in chapter 3 and 4 are input for the development of the Street Function Index (**Gatufunktionsindex**). This index aims to assess how existing and designed streets combine five different street functions - social, ecologic, economic, technical and traffic. The Street Function Index is developed in one of the other work packages and is not a direct result of the literature review discussed here, but the review aims to provide relevant input for the further development of the Street Function Index, in this chapter, first, the proposed Street Function Index is presented; second, an overview of existing indices to evaluate the performance of streets found in the systematic review is given; third, we propose how these findings and results presented in the earlier chapters can be integrated in the Street Function Index.

Street Function Index
In order to map multifunctionality in street environments, the Smart streets project developed the idea for the Street Function Index (Nordström et al. 2019). The purpose of the Street Function Index is to compare different street designs or realized streets using a gross list of street features that represent a function. The purpose is not to explain why some functions occur, but simply describe what features are present in the street and compare the multifunctionality of streets in terms of the social, ecologic, economic, technical and traffic function. In a next step, these functional profiles will be related to street typology, location, geometry and design in design guidelines, one of the other end products of the Smart Street project.

Nordström et al. (2019) https://smartagator.wordpress.com/2019/09/20/gatufunktionsindex-test-av-ett-analysverktyg-for-att-mata-gators-mangfunktionalitet/

The selection of features is based on a reading of national and international design guidelines such as Urban Mobility, Health and Public Spaces: Reshaping Urban Landscapes (2018), Urban Mobility Innovation Index (2017), Global Street Design Guide (2017) and Gata Stockholm Handbook (2019). An important principle for the selection of features is whether it contributes to sustainable urban development, as described, for example, in the UN Sustainability Goal (2018) and UN Habitat's New Urban Agenda (2018). Alongside this reading of guidelines, the literature search of empirical studies that is at the core of this report, has also been conducted and could be used to provide input to the weighting of the different features based on their ability to support ecologic, economic, technical and/or traffic functions. We will return to this at the end of this chapter.

After listing all relevant features, the list is reduced to 100 features that was deemed sufficient and powerful in its simplicity. These 100 features are clustered in function groups that we have discussed earlier: social, ecologic, economic, technical and traffic. The social functions include safety, recreation, health and liveability. The economic functions are about the possibility of economic exchange in the street space. The traffic functions focus on accessibility and accessibility for different groups and modes of transport. The ecological functions are about the management of water, air purification and habitats for both flora and fauna. The technical functions deal with ICT, resource management such as wastewater, waste and water as well as the properties of the materials such as durability and wear resistance. Currently, the number of features within each function group is basically the result of the search of features and no weighting or normalization method is used to for instance give each of these function groups the same importance for the final score.

For each feature, a simple variable is defined that allows the objective measurement of the presence of the function in a street. In some case simple binary variables are used such as the presence of benches or other features to sit on or, in case of the "walking" function, the presence of at least 2.5 meters of walkway. Besides these binary variables, other more complex variables are used such as for "road safety" where both design, speed and traffic flow data are included. The Street Function Index should not primarily be seen as a "scoring" where many functions mean that the street is better, but the index simply shows that the street has more features and thus more functions. By weighing the features in relation to their ability to contribute to sustainable development, the index could also be used to assess the performance of the streets.

Figure 8.
Street Function Index with five main function groups: social, ecologic, economic, technical and traffic function.

Figure 8 is earlier published in Nordström et al. (2019) https://smartagator.wordpress.com/2019/09/20/gatufunktionsindex-test-av-ett-analysverktyg-for-att-mata-gators-mangfunktionalitet/

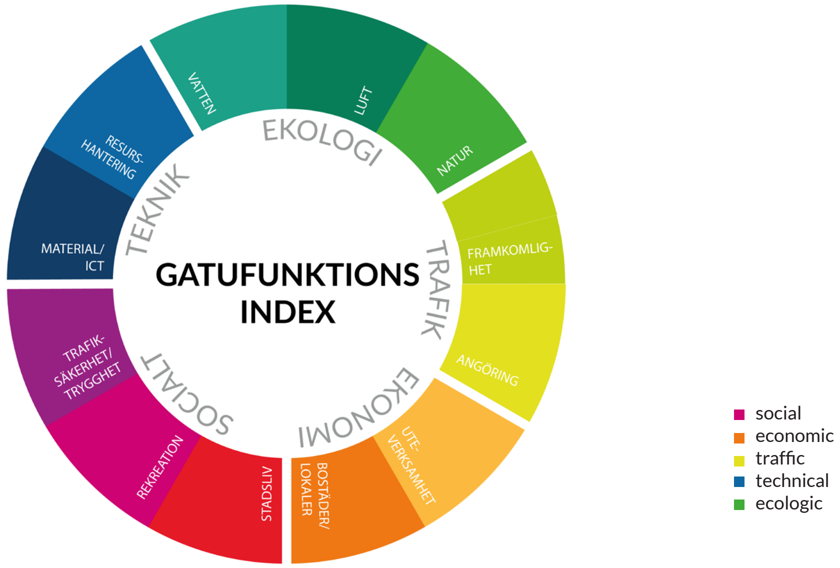
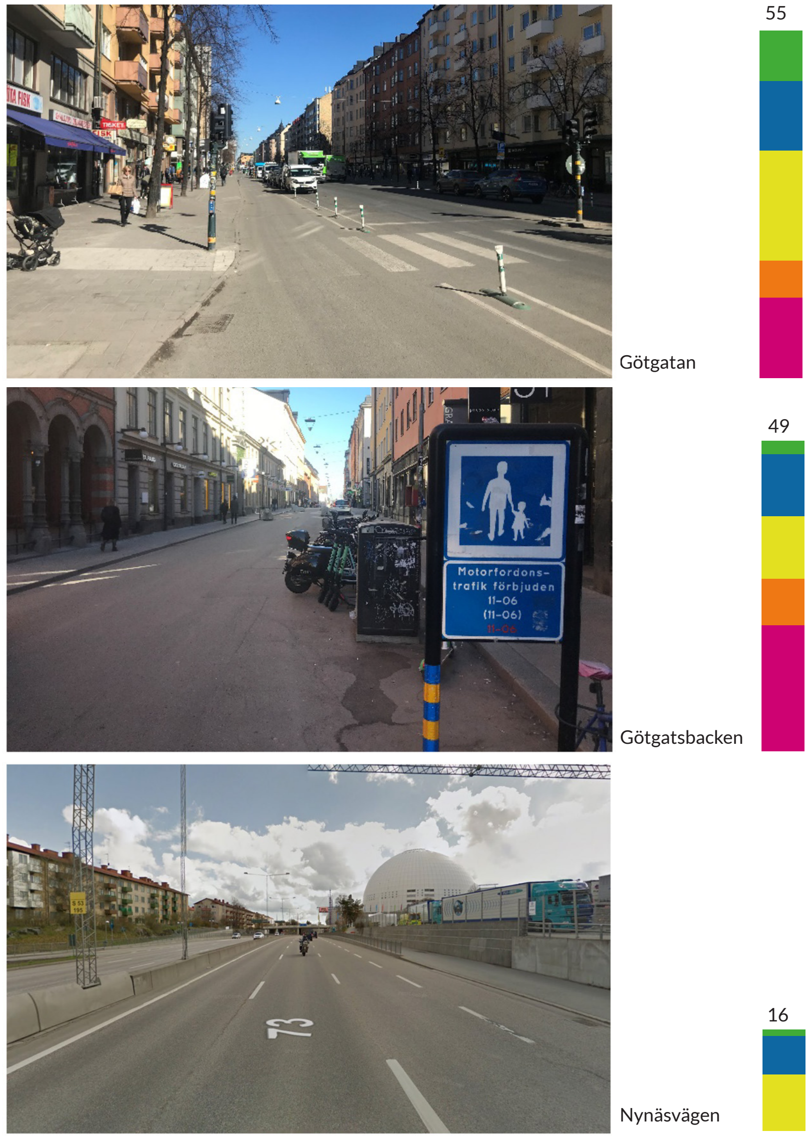


Figure 9.
Examples of streets and their Street Function Index score.

Figure 9 is derived from an earlier publication by Nordström et al. (2019) https://smartagator.wordpress.com/2019/09/20/gatufunktionsindex-test-av-ett-analysverktyg-for-att-mata-gators-mangfunktionalitet/



Review of relevant indices to evaluate the performance of streets

In the systematic review, 29 papers relate to indices to evaluate the performance of streets of which 13 were selected for full paper reading but only 7 are used for writing this report because these were sufficient to present eight unique and for the project relevant indices:

1. Pedestrian Safety Index (PSI) (Asadi-Shekari et al. 2015);
2. Bicycle safety index (BSI) (Asadi-Shekari et al. 2015);
3. Walk Score (Hirsch et al. (2013);
4. Transit Score (Hirsch et al. (2013);
5. Level-of-service (LOS) methodology (Brozen et al. 2014);
6. Healthy Development Index (HDI) (Health, 2011);
7. Walkability Index developed by Frank et al. (2009):
8. Green Road Rating (Park and Ahn, 2015).

The Pedestrian Safety Index (PSI), discussed in Asadi-Shekari et al. (2015a), uses 24 indicators that are extracted from 20 guidelines, developed earlier in various countries. The indicators used are for instance traffic speed, barriers, traffic lanes, pavement, landscaping and trees. A coefficient is used to define the importance of the 24 indicators. This step of weighting is often arbitrary, but in the end affects the score a street receives when assessed. To arrive at some objectivity, PSI is based on earlier developed guidelines and the frequency this indicator is used. This defines the default setting of the coefficient, but it also allows for adjustments and this makes PSI flexible in its application, but makes comparisons of the scores of different cities that have chosen their own weighting, more difficult.

The same authors (Asadi-Shekari et al., 2015b) developed a bicycle safety index (BSI) using a similar method, but for this purpose, 11 indicators were identified in 23 guidelines.

The Walk Score and Transit Score by Hirsch et al. (2013) produces scores from 0 to 100, using an algorithm based on distance to various categories of amenities that re known to affect walking (e.g., distance to restaurants, shopping, schools, parks, and entertainment) using a decay function that gives less points to more distant amenities, with no points given after a 30 minute walk. These weighted scores are then summed and adjusted for street-network characteristics, such that areas with low intersection density and high block length receive lower scores.

The Transit Score also provides a 0–100 rating indicating how well a specific address is served by public transportation (e.g., bus, subway, or light rail). While the Walk Score and Transit Score are weighed based on spatial variables, the PSI was weighed based on its frequency of mentions and usage in design guidelines. Very important to mention is that the Walk Score and Transit Score are empirically tested and it was shown that higher scores are associated with higher amount of transport and leisure walking in a large, multicity, and multi-ethnicity sample. The empirical test provides direct validation of the scores that PSI and BSI lack.

The level-of-service (LOS) methodology, introduced in 1965, measured originally a street's capacity for automobiles only (Brozen et al. 2014). Since the 1970s, multimodal approaches (pedestrian and bicycle LOS) for determining the performance of streets were introduced such as the High Capactity Manual (HCM) 2010 for bicycles and pedestrians, the Bicycle Environmental Quality Index (BEQI) and the Pedestrian Environmental Quality Index (PEQI) created by the Department of Public Health of San Francisco, California and the protocol for bicycles and pedestrians developed by the City of Charlotte, North Carolina.

Brozen et al. (2014) compare these different protocols that are developed based on the LOS methodology and show that the HCM 2010 method is overly sensitive to areas with high parking occupancy and traffic volume in comparison to the other two indices. PEQI, on the other hand, is sensitive to indicators included only in this index such as street lighting, trees, nearby retail locations, and obstruction free sidewalks. Crossing distance is the most important factor in the intersection scoring of the Charlotte LOS protocol.

Overall, the paper concludes that the three indices were at complete disagreement in scoring intersections for bicyclists, because they use different variables and different weights. These differences are explained in part by the different goals of the tool and sheds light on the importance of the weighting of the indicators or features used.

The Healthy Development Index (HDI) (Health, 2011) relates mostly to physical activity and shows similarity to the Walk Score discussed earlier. HDI includes more elements though, to be precise, it includes seven built environment elements such as density, proximity, land use mix, connectivity, road network and sidewalk characteristics, parking and aesthetics and human scale. Each element is evaluated using a series of measures/indicators. Weighting the indicators is discussed, but not solved.

Similar indicators are used in the Walkability Index developed by Frank et al. (2009): density, service proximity, land use mix (or entropy score) and street connectivity.

The Green Road Rating (GRR) system is based on similar rating systems for buildings such as Leadership in Energy and Environmental Design (LEED), Green Globes, and the Building Research Establishment Environmental Assessment Method (BREEAM). The GRR system provides guidelines that support green practices and technologies in road construction with the aim to reduce the road's environmental impact while enhancing its associated social and economic benefits (Park and Ahn, 2015). In the paper by Park and Ahn (ibid.), several existing green road rating systems developed in the US are reviewed and used to develop the GRR for South Korea. Four main goal categories were defined for the GRR (ibid. p. 255-256):

- Green Road Design/Pavement Technologies: advanced green design and pavement technologies can reduce both negative environmental impacts and carbon emissions.
- Green Environment: this category aims to minimise environmental pollution, reduce emissions and pollution, provide eco-friendly roads, and support connections with the local community.
- Green Traffic Systems: this benefits road users by improving safety and energy efficiency through smart road operation, as well as providing an eco-friendly traffic system.
- Green Resources and Energy: the aim here is to minimise the use of resources through recycling, utilising renewable energy, and minimal movement of resources.

For these four categories, a total of 37 different indicators are proposed and weighted. To weight the importance of the four main categories interviews with 26 experts were conducted, which revealed that Green Environment (0.35) was ranked as the most important category, above Green Road Design/Pavement Technology (0.27), Green Resources and Energy (0.21), and Green Traffic Systems (0.17). Within these categories, also the indicators are weighted, resulting in a system where, based on 37 indicators and 4 categories, 100 points can be scores and an additional 10 for innovative solutions not included in the system.

The indices reviewed all have a very clear objective, which is included in its naming. The Walkability Index aims at improving sustainable modes of transport. Pedestrian safety is aiming for safer streets while the Healthy Development Index aims for more healthy environments in general, albeit the focus is very much on walkability. The level-of-service (LOS) methodology was originally an index to measure a street's capacity for automobiles and has later been developed for other modalities. The GRR focuses on a wide variety of environmental aspects such as ecological connectivity and material life-cycle assessments.

These clear performative goals contrast the Function Street Index that does not aim to promote one performance but focuses on multifunctionality. The 100 functions listed are derived from street design guidelines in similar ways as the Pedestrian Safety Index, but with a less sophisticated system for weighing. As was shown in the protocols and scores developed in line with LOS methodology, the choice of variables as well as their weighing is highly affecting the outcomes. A bias towards certain function groups in the Function Street Index should thus be critically assessed. The Green Road Rating (GRR) system can be an interesting index to learn from. It defines variables based on existing guidelines and rating systems and after grouping these in four main categories, expert knowledge is used to weigh these categories in the final score. A similar approach could be used to balance the five function groups in the Function Street Index: social, ecologic, economic, technical and traffic.

Furthermore, the systematic review of the empirical studies can give input for the inclusion, exclusion and weighing of the 100. features proposed in the Function Street Index. Instead of empirically testing the performance of the index as was done for the Walk Score and Transit Score, we propose to use empirical evidence that the 100 features contribute to the the social, ecologic, economic, technical and/or traffic function. For that reason, in the next section, we will discuss how the results of the systematic review could be integrated in the Function Street Index.

Integration of empirical findings in the Street Function Index

To integrate the findings of the review, two issues will be raised that we, based on the review of indices above, find most important. First, the 100 features currently included in the index and second, the weighting of them.

We propose to simply mirror the 100 proposed features of the index with the physical factors highlighted as important in the empirical studies. While the Walk Score and Transit Score tested their index empirically, we thus propose to include the empirical validation of the 100 features. This can be done simply by checking whether the 100 features of the index are mentioned in the empirical studies. Besides this binary approach, also some kind of weighting system could be added and a relatively simple way forward could be to use the number of papers that mention this feature. However, this score does not necessarily highlight the importance of the feature. It could also mean that it is simply used a lot in empirical studies because of data availability or ease of measurement. We therefore propose to instead, in line with the objective of the index, use the multifunctionality if the factor as principle for weighting. In other words, features that contribute to more than one function are weighted higher than features that only provide one function.

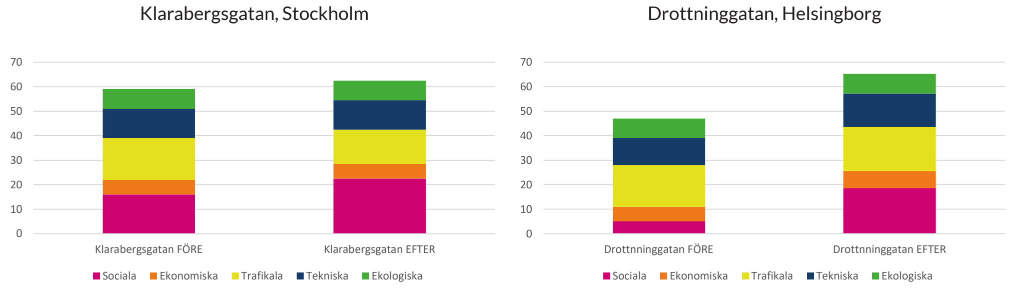
Besides the validation and weighting of the 100 features, we should also develop a method to weight the main function groups, that is, the social, ecologic, economic, technical and traffic function. Currently, the number of features within each function group defines its importance in the total score. One option is to weight them equally and thus, independent on the amount of features that are included, each can contribute to the total score with max 20 points. To avoid a bias towards one of the function groups, we propose to start with valuing them equally or use interviews with experts to define a weighing in similar ways as in the Green Road Rating (GRR) system discussed earlier. This weighing of the function groups could also be made site or street type specific as was proposed in some of the indices reviewed. There might be street types where for various reasons, the social functions are more important than the traffic functions. A third option is to have a default setting where the function groups are valued equally, but that the end user can adjust this.

Summarising the above, we propose two possible modifications of the current Street Function Index:

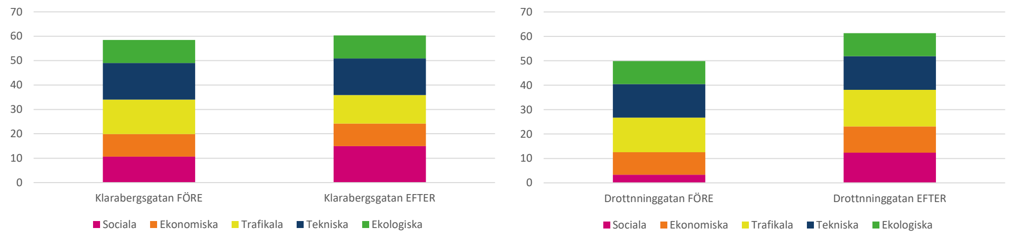
The first follows the function groups and accompanying list of features as proposed in the Street Function Index, but a weighting system of the function groups is added that is independent of the number of features included in this group so that each groups can get a maximum score of 20. The five groups together result then in a maximum score of 100. The reason for this is that we do not know whether more features in a function group reflects importance. Instead of valuing each group similar, the weighting could also be made modifiable by the end-user or be adjusted for different street types. It could later also be complemented by expert knowledge weighting as discussed above.

For instance, the social function group includes 30 features, while the economic function group includes only 13 features. To normalize this variation in the number of features, the features that support the social function can be multiplied by 0,67 (i.e. 20/30), while the features that support the economic function are multiplied by 1,54 (i.e. 20/13).

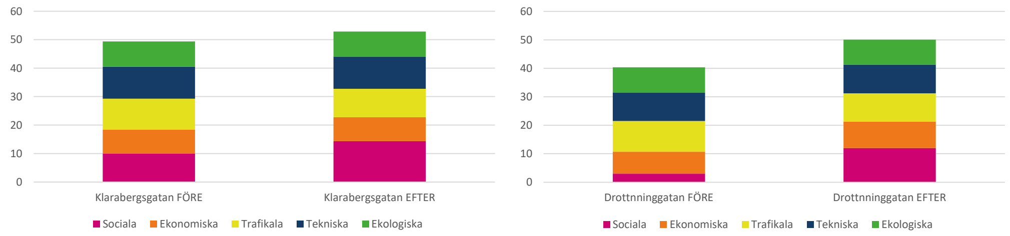
Figure 10.
COmparison of different weighting systems of the Strret Function Index, tested in two streets.



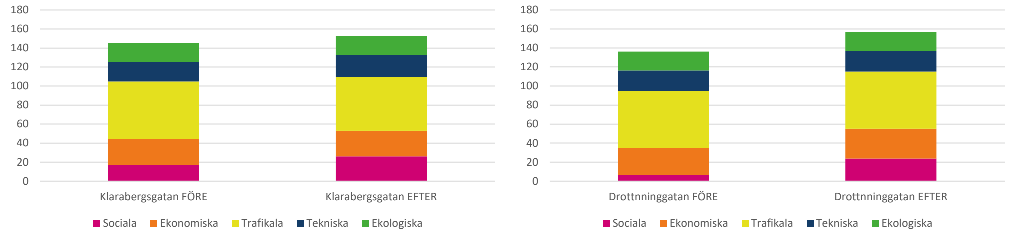
10a Count of features



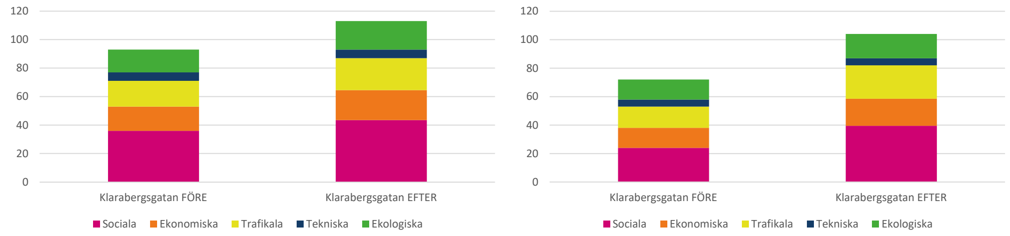
10b Normalized count of features



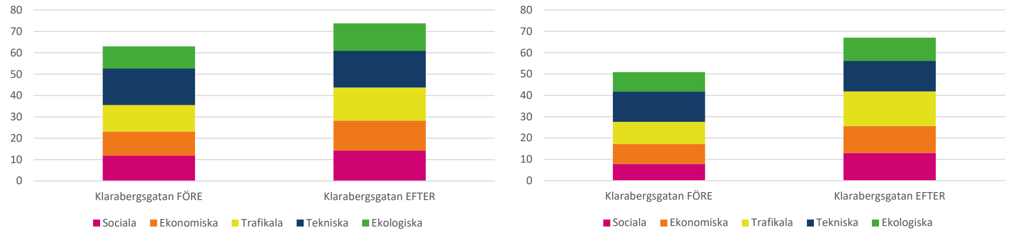
10c Normalized count of features weighted by empircal support



10d Normalized count of features weighted by empircal support and multifunctionality



10e Count of functions



10f Normalized count of functions

The data used in figure 10 is collected and published by Bergström et al. (2019) https://smartagator.wordpress.com/2019/12/17/sveriges-smartaste-gator/

In **figure 10a**, the results of the simple feature count are shown for two streets (Klarabergsgatan i Stockholm och Drottninggatan i Helsingborg), depicting the scores in these streets before and after various design interventions (Bergström et al. 2019). **Figure 10b** shows the results after normalization, that is, when each function category can have a maximum score of 20, independt of the amount of features in the function group. When comparing the reslts of these two methods, in the simple count of features, it seems as if the economic function is neglected with a very low share in the feature count. However, the reason for the low share might not be caused by the absence of features that support the economic function, but by the amount of features that are included in the index. After normalization, the role of the economic function is more in parity with the other functions. When comparing the share of the social function in Drottninggatan, both methods show a clear increase after the interventions.

Bergström et al. (2019) https://smartagator.wordpress.com/2019/12/17/sveriges-smartaste-gator/

Besides normalization, a weighting system is proposed based on the empirical evidence found in the systematic review. This could be done by accounting for the amount of times a feature is mentioned in the papers reviewed, but this does not necessarily reflect importance. We therefore propose to simply count the features without evidence half, while the features with proved effect are fully counted. For example, the feature benche is found to have positive effect for the social function and is thus receives a full count (i.e. 1,0), while no empirical proof is found for an outdoor gym that therefore is only counted half (i.e. 0,5). Results are shon in **figure 10c**. In similar manner, weighting can be added based on the multifunctionality of the feature, where a feature that supports multiple functions such as flowering that serves both a social, ecological and economic function, is weighted higher than features that only support one function. In figure **10d**, the results of the multifunctionality weighting methods is shown.

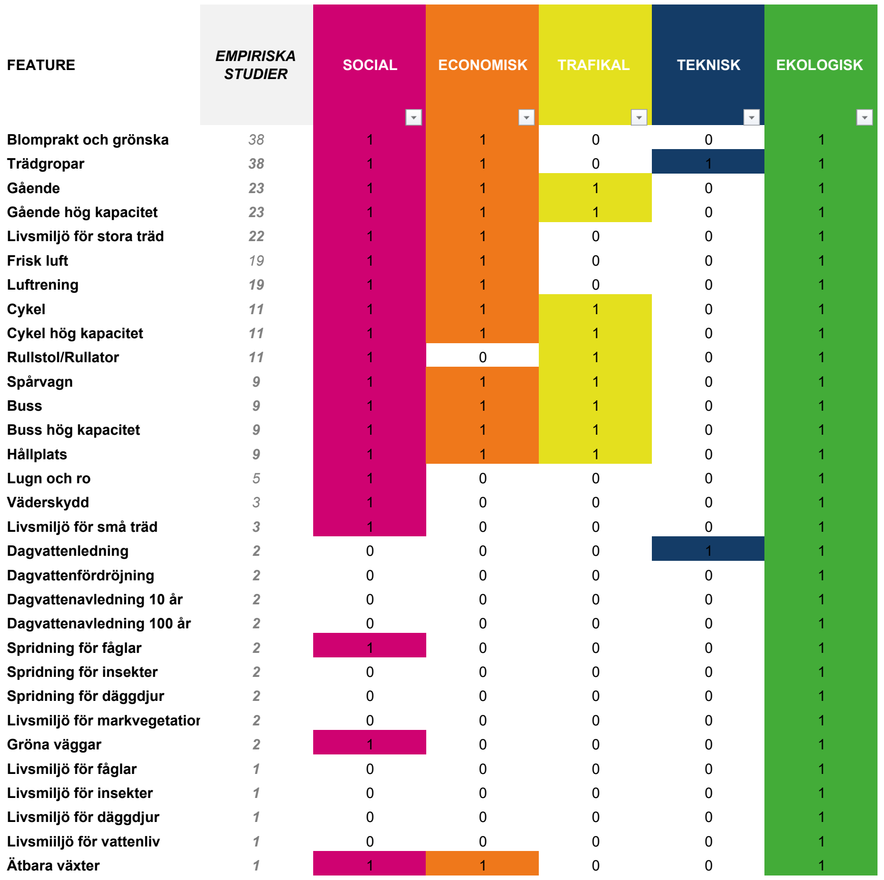
The difference between the normalized results and the weighting based on empirical evidence shows very little difference. However, the weighting based on multifunctionality is causing huge changes in the distribution of the different function scores, especially the traffic function increases a lot, because many of the features included here do not only affect mobility, but also the other functions. For instance, adding features that support walking, is not only a traffic function but also has affects health, one of the social functions, promotes city life, which in turn is positive for economic functions and reduces car usage and thus reduces greenhouse gas emissions, an environmental function. However, the diagram does not reflect the actual functions that are added, but gives the traffic function a higher score based on the multifunctionality of its features. This might be confusing when comparing streets and their multifunctionality and we therefore propose a second approach where the functions are depicted instead of the features.

Instead of categorizing the 100 features according to their original function, a matrix is developed where each feature can be counted multiple times in case it contributes to more than one function. In other words, the bench as feature is only counted once as it contributes to only the social function, while the street tree contributes to the social, economic and ecological function and thus adds one point in each of these function groups. In **figure 10e**, the results of this approach are shown. **Figure 10f** shows the same results, but now normalized so that each function groups can get at the most 20 points.

The differences between these various methods are huge and it is therefore important to be very clear about what they describe and based on that, discuss what best suits the objective with the index. The diagrams in **figure 10** provide an overview of these different methods where **10a-d** group the features before weighting. **Figure 10e-f** ignores the grouping of features in different groups and only looks at the function they provide, which results in the overview of functions. The input, 100 features, is thus separated from the output: the social, economic, traffic, technical and ecologic function. If the Street Function Index is aiming at describing the various street functions as its name suggests, the last method might be the most appropriate. We should, however, discuss and test this with experts from practice.

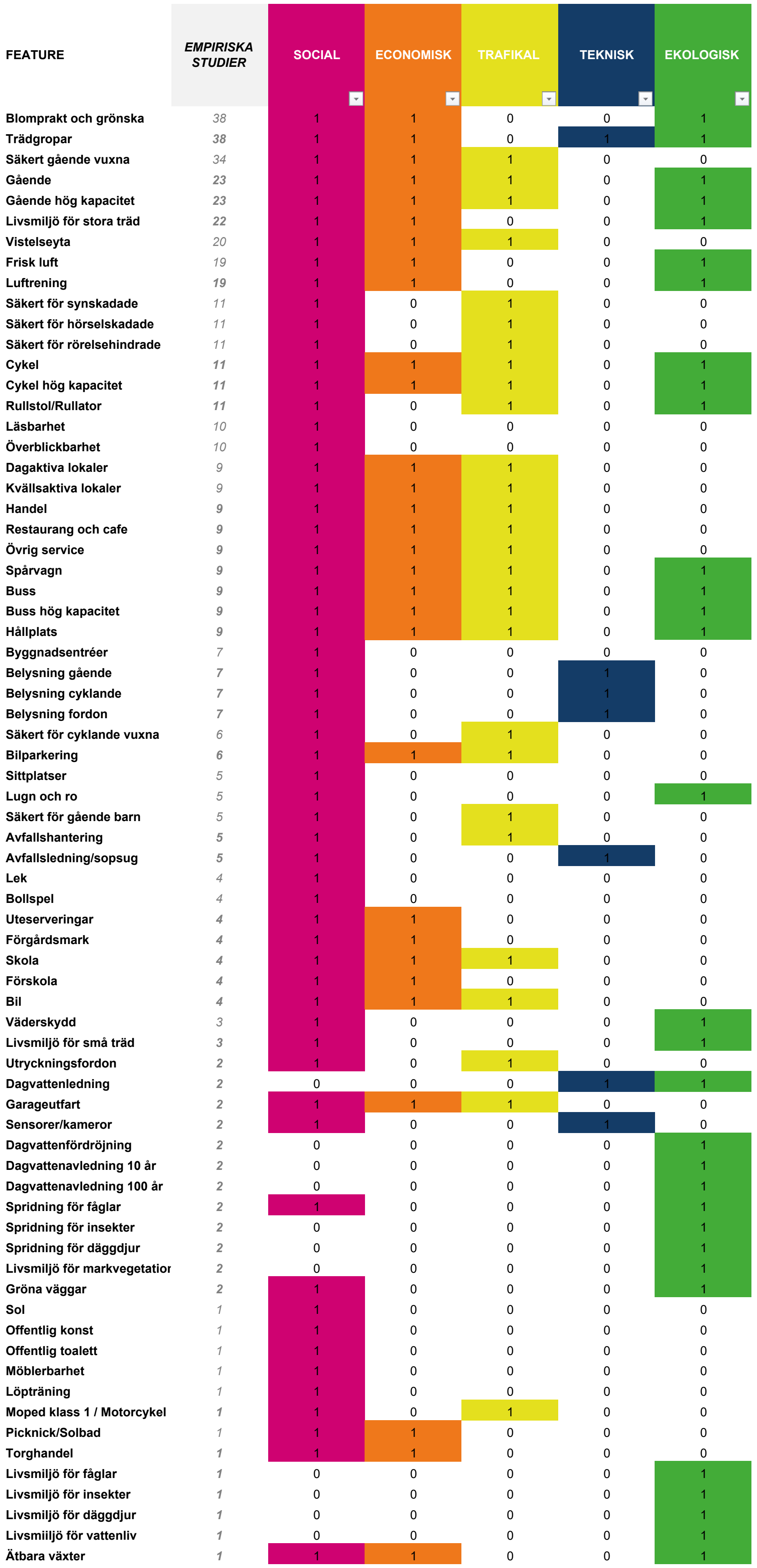
The features in **figure 10** where we do not have empirical support for from the review, score 0,5 points while those with empirical support score 1. The same logic applies to all the approaches in figure 10 and also for the overviews in **figure 11**.

The matrix with features and functions can also be used to interactively make a list of features that fits your requirements. Through the filtering function in Excel, the features can be sorted to based on their support of one or more functions. See **figure 11** and **12**.



FEATURE	*EMPIRISKA STUDIER*	SOCIAL	ECONOMISK	TRAFIKAL	TEKNISK	EKOLOGISK
Blomprakt och grönska	38	1	1	0	0	1
Trädgropar	38	1	1	0	1	1
Gående	23	1	1	1	0	1
Gående hög kapacitet	23	1	1	1	0	1
Livsmiljö för stora träd	22	1	1	0	0	1
Frisk luft	19	1	1	0	0	1
Luftrening	19	1	1	0	0	1
Cykel	11	1	1	1	0	1
Cykel hög kapacitet	11	1	1	1	0	1
Rullstol/Rullator	11	1	0	1	0	1
Spårvagn	9	1	1	1	0	1
Buss	9	1	1	1	0	1
Buss hög kapacitet	9	1	1	1	0	1
Hållplats	9	1	1	1	0	1
Lugn och ro	5	1	0	0	0	1
Väderskydd	3	1	0	0	0	1
Livsmiljö för små träd	3	1	0	0	0	1
Dagvattenledning	2	0	0	0	1	1
Dagvattenfördröjning	2	0	0	0	0	1
Dagvattenavledning 10 år	2	0	0	0	0	1
Dagvattenavledning 100 år	2	0	0	0	0	1
Spridning för fåglar	2	1	0	0	0	1
Spridning för insekter	2	0	0	0	0	1
Spridning för däggdjur	2	0	0	0	0	1
Livsmiljö för markvegetatior	2	0	0	0	0	1
Gröna väggar	2	1	0	0	0	1
Livsmiljö för fåglar	1	0	0	0	0	1
Livsmiljö för insekter	1	0	0	0	0	1
Livsmiljö för däggdjur	1	0	0	0	0	1
Livsmiiljö för vattenliv	1	0	0	0	0	1
Ätbara växter	1	1	1	0	0	1

Figure 11.
Database with all features and functions that can be sorted using the Filter Function in Excel. "1" means that the function is supported by the feature according to the literature review and "0" means that the function is not supported. Result shown here is based on the filter "Ecological function = 1" showing only the features that support the ecological function according to the literature review.



FEATURE	*EMPIRISKA STUDIER*	SOCIAL	ECONOMISK	TRAFIKAL	TEKNISK	EKOLOGISK
Blomprakt och grönska	38	1	1	0	0	1
Trädgropar	38	1	1	0	1	1
Säkert gående vuxna	34	1	1	1	0	0
Gående	23	1	1	1	0	1
Gående hög kapacitet	23	1	1	1	0	1
Livsmiljö för stora träd	22	1	1	0	0	1
Vistelseyta	20	1	1	1	0	0
Frisk luft	19	1	1	0	0	1
Luftrening	19	1	1	0	0	1
Säkert för synskadade	11	1	0	1	0	0
Säkert för hörselskadade	11	1	0	1	0	0
Säkert för rörelsehindrade	11	1	0	1	0	0
Cykel	11	1	1	1	0	1
Cykel hög kapacitet	11	1	1	1	0	1
Rullstol/Rullator	11	1	0	1	0	1
Läsbarhet	10	1	0	0	0	0
Överblickbarhet	10	1	0	0	0	0
Dagaktiva lokaler	9	1	1	1	0	0
Kvällsaktiva lokaler	9	1	1	1	0	0
Handel	9	1	1	1	0	0
Restaurang och cafe	9	1	1	1	0	0
Övrig service	9	1	1	1	0	0
Spårvagn	9	1	1	1	0	1
Buss	9	1	1	1	0	1
Buss hög kapacitet	9	1	1	1	0	1
Hållplats	9	1	1	1	0	1
Byggnadsentréer	7	1	0	0	0	0
Belysning gående	7	1	0	0	1	0
Belysning cyklande	7	1	0	0	1	0
Belysning fordon	7	1	0	0	1	0
Säkert för cyklande vuxna	6	1	0	1	0	0
Bilparkering	6	1	1	1	0	0
Sittplatser	5	1	0	0	0	0
Lugn och ro	5	1	0	0	0	1
Säkert för gående barn	5	1	0	1	0	0
Avfallshantering	5	1	0	1	0	0
Avfallsledning/sopsug	5	1	0	0	1	0
Lek	4	1	0	0	0	0
Bollspel	4	1	0	0	0	0
Uteserveringar	4	1	1	0	0	0
Förgårdsmark	4	1	1	0	0	0
Skola	4	1	1	1	0	0
Förskola	4	1	1	0	0	0
Bil	4	1	1	1	0	0
Väderskydd	3	1	0	0	0	1
Livsmiljö för små träd	3	1	0	0	0	1
Utryckningsfordon	2	1	0	1	0	0
Dagvattenledning	2	0	0	0	1	1
Garageutfart	2	1	1	1	0	0
Sensorer/kameror	2	1	0	0	1	0
Dagvattenfördröjning	2	0	0	0	0	1
Dagvattenavledning 10 år	2	0	0	0	0	1
Dagvattenavledning 100 år	2	0	0	0	0	1
Spridning för fåglar	2	1	0	0	0	1
Spridning för insekter	2	0	0	0	0	1
Spridning för däggdjur	2	0	0	0	0	1
Livsmiljö för markvegetatior	2	0	0	0	0	1
Gröna väggar	2	1	0	0	0	1
Sol	1	1	0	0	0	0
Offentlig konst	1	1	0	0	0	0
Offentlig toalett	1	1	0	0	0	0
Möblerbarhet	1	1	0	0	0	0
Löpträning	1	1	0	0	0	0
Moped klass 1 / Motorcykel	1	1	0	1	0	0
Picknick/Solbad	1	1	1	0	0	0
Torghandel	1	1	1	0	0	0
Livsmiljö för fåglar	1	0	0	0	0	1
Livsmiljö för insekter	1	0	0	0	0	1
Livsmiljö för däggdjur	1	0	0	0	0	1
Livsmiiljö för vattenliv	1	0	0	0	0	1
Ätbara växter	1	1	1	0	0	1

Figure 12.
Result shown in figure 12 is based on the filter "Social function = 1" showing only the features that support the social function according to the literature review.

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