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Crime Prevention Based on the Strategic Mapping of Living Conditions

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Abstract: This paper presents a theoretically and methodologically grounded GIS-based model for the measurement and mapping of an index of living conditions in urban residential areas across Sweden. Further, the model is compared and evaluated using the Swedish Police's assessment of crime-exposed areas. The results indicate that the geographically measured vulnerable living conditions overlap to a large extent with the areas assessed to be crime-exposed by the Swedish Police. Over 61% of the police-defined crime-exposed areas are characterized by vulnerable living conditions. The results also show that this overlap is not perfect and that there are vulnerable areas that are not included in the police's assessment of crime-exposed areas, but which are nonetheless characterized by vulnerable living conditions that could negatively affect the development of crime. It is also proposed that the model and the mapped index of living conditions can provide a more well-grounded scientific basis for the police's assessment work. As a first step, the Swedish police have implemented the model and the mapped index in the work process employed in their annual identification of crime-exposed or at-risk areas. In addition to assisting the police, the model and the mapped index could also be used to support other societal actors working with vulnerable areas.

Keywords: living conditions; crime prevention; crime-exposed areas; GIS-model; strategic mapping

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1. Introduction

People's living conditions are of fundamental importance for their developmental opportunities. Living conditions may be determined by different factors, such as family situations, relationships with and support from surrounding communities, financial conditions, and the health of people living in different residential areas. Unequal living conditions affect various aspects of life [1], e.g., health [2], school results [3,4], and exposure to crime [5]. Previous research has identified variables such as educational level, employment rate, income, foreign background, single-parent households, the number of children and adolescents in different age groups, and overcrowding as strong indicators of different levels of living conditions [6–10].

Early criminological research indicated that areas characterized by vulnerable living conditions were also more vulnerable to crime [11–17]. This research also indicated that vulnerable areas are exposed to crime to varying extents. Some deprived areas have high rates of both violent and other crimes, while others do not differ significantly from non-vulnerable residential areas [18]. These variations have been addressed using several criminological theories, such as the social disorganization theory and the collective efficacy theory.

Early measurements of social disorganization focused on socioeconomic status, ethnic heterogeneity, and residential instability in order to better capture neighborhood conditions. In an influential development of the theory, family disruption and urbanization were added

to complement these variables [19]. The social disorganization theory has also evolved over time and become more focused on social control [20].

Later, the social disorganization theory developed into the collective efficacy theory, which highlights the importance of trust and agency as key factors in relation to crime. Alongside this theoretical development, the concept of concentrated disadvantage was introduced, focusing on both socioeconomic status and race as factors that influence disadvantage [16]. Collective efficacy, as measured by social cohesion among residents, may reduce the number of violent crimes in vulnerable areas [16]. Poor neighborhoods with high population turnover and an ethnically heterogeneous population will struggle to maintain social control and organization, and thus become socially disorganized, which may, in turn, lead to more crime [19].

Assessments of crime-exposed areas are usually based on statistics [21]. However, complementary geographical methods may also be important for the police's and other actors' assessments of crime-exposed areas. Area assessments based on maps, sketch maps, hotspots of crime, and socio-economic disadvantage are relatively common worldwide. These methods have been employed in order to, for example, increase police knowledge of the areas in which they patrol [22,23], or present and compare police and public perceptions of crime in different neighborhoods [24–26]. Studies show that there are differences between the perceptions and assessments of the police and other residents [27,28], and they also demonstrate a need for more scientifically grounded approaches to supplement experience-based and more subjective assessments of crime-exposed urban areas [29]. In Sweden, the Swedish Police have assessed and defined 60 crime-exposed areas, in which citizens' exposure to crime has a strong impact on their daily lives in the local community [30]. Other crime-exposed areas have also been identified and reported by local police organizations, and there are now a total of over 180 crime-exposed areas in Sweden. However, the mapping and demarcation of these areas are still primarily based on individual police officers' experiences and perceptions of the residential areas in question.

This paper's approach to living conditions is based on previous studies and theories of social stress [31–33], which have been operationalized into geographically measurable variables and indices in order to analyze the relationships between living conditions and expressions of social disorder. For example, different indices of living conditions have previously been applied to and found to explain geographical differences in arson and crime in large Swedish cities [6,7,34,35]. Thus, the theoretical and methodological approach used in this paper may be seen as an extension of existing criminological approaches, such as those based on the social disorganization and collective efficacy theories, which address similar geographical differences in crime and which use similar indices to measure vulnerability [19,35].

The purpose of this paper is to present and apply a theoretically and methodologically grounded GIS-based model for the measurement and mapping of an index of living conditions in urban residential areas across Sweden, and, further, to compare and evaluate this approach in relation to the Swedish Police's assessment of local problem areas and crime-exposed areas. The model and the map of indexed living conditions developed in this paper are presented and analyzed in relation to two related, but independent, geographical datasets comprised of (1) local problem areas assessed on the basis of an operational police perspective, and (2) vulnerable areas identified on the basis of socio-economic status. One objective in developing the model, and its application in the form of a national database and web map, is that this will form the basis for further analyses of living conditions in various areas.

2. Materials and Methods

2.1. Material

The socio-economic and demographic data used to index living conditions have been collected from Statistics Sweden (Statistiska centralbyrån-SCB). The statistical data are mapped onto 250 × 250 m grids that cover mainly urban areas across Sweden with more

than 200 inhabitants. These 250 × 250 m grids have a better geographical resolution than other Swedish geographical divisions, such as Demographic Statistics Areas (DeSO) or Small Areas for Market Statistics (SAMS) [36], and also compared to the Lower-layer Super Output Areas (LSOA) employed in similar research in England [18]. The indexation of living conditions is based on the following variables:

- Education—pre-upper-secondary education (% of pop.);
- Employment rate—employed persons aged 20–64 (% of pop.);
- Income—net median income 20+ years (SEK);
- Foreign background—population of foreign background (% of pop.);
- Marital status—single parents with children still living at home (% of pop.);
- Population per square kilometer (pop/km^2).

In addition to the socio-economic and demographic data, the study employs a dataset comprising the Swedish Police's own assessment of crime-exposed local problem areas (LPAs) from an operational police perspective. Based on a structured assessment, each local police district has been required to manually delineate problem areas on a map and report them to the national police level. This first assessment, from 2018 to 2019, resulted in over 180 mapped polygons across urban and rural areas throughout Sweden. In the current study, this data set is used primarily to illustrate LPAs in central parts of cities.

Another police dataset employed in this article, which in part overlaps with the LPAs, is the National Operations Department's (NOA) assessment of areas exposed to crime. This national assessment is based on annual reports from the country's local police areas, which are in turn produced using a structured and stepwise assessment method [30]. The overall assessment is mainly carried out from a police perspective, with a specific focus on citizens' exposure to crime and criminal networks and their impact on local communities [8,30]. Approximately 60 such crime-exposed areas were identified in 2019. However, this number changes over time depending on the results of the assessment and developments in the relevant areas' crime levels. Another tendency is that these crime-exposed areas are not evenly distributed across Sweden's local police districts. Instead, they tend to be concentrated in certain (metropolitan) areas in the southern parts of Sweden, and many of these are stable over time (Figure 1).

In its assessment, the NOA employs three different categories: exposed areas, particularly exposed areas, and risk areas. These areas are described as follows:

- An exposed area is a geographically defined space, characterized by low socio-economic status, in which criminal actors have an impact on the local community. This impact can be exerted via direct pressure on people, organizations, and businesses—for example, via threats and extortion—or indirectly, via acts of public violence that risk harming third-party citizens, open drug trafficking, and dissatisfaction with societal institutions. In consequence, residents in the exposed areas may experience insecurity and fear, which leads to a reduced tendency to report crime and to participate in the legal process. The situation is considered serious.
- In a particularly exposed area, the situation is even more serious. From a police perspective, such areas are characterized by a general reluctance among the population to participate in legal proceedings. There are also systematic threats and acts of violence against witnesses, injured parties, and those who oppose criminals. The situation in these areas makes it almost impossible for the police to carry out their mission. This serious situation also tends to become normalized. Residents and other actors no longer reflect on the fact that their area is different from other areas. Particularly exposed areas are further characterized by pronounced features of parallel social structures and extremism, e.g., systematic violations of religious freedoms, or powerful fundamentalist influences that restrict human rights and freedoms. These areas may also have residents who travel abroad to participate in armed conflicts and a high concentration of criminals. In addition, the presence of several adjacent particularly exposed areas poses a greater risk of more geographically widespread criminal activities and networks.

- Risk areas constitute an intermediate level between exposed and particularly exposed areas. The situation is serious, and there is a risk that the area will become a particularly exposed area if no efforts are made to curb this development. Negative developments in a risk area can be prevented if adequate measures are implemented [30].

It should be emphasized that the assessment of exposed areas from a police perspective, including all three categories described above, has been carried out completely independently of the modeling and mapping of living conditions presented in this paper. It should also be emphasized that the term "*exposed area*" is used in this paper, with some exceptions in the analysis, as a generic term for all three categories.

The base map employed in the paper comprises: ESRI, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Sources: Esri, Here, Garmin, FAO, NOAA, USGS, © Open StreetMap Contributors, and the GIS User Community.



Figure 1. Areas assessed to be crime-exposed in Sweden, 2019.

2.2. Methods

The indexation of living conditions has been conducted in four principal steps, involving intermediate indices of: (a) family conditions, (b) housing (segregation) conditions, and (c) economic conditions. These conditions are described more extensively in the theoretical model in Section 3 and in Figure 2 below. The four steps, which include value assignment and equal weighting, are as follows:

1. Each of the variables presented above (education, employment rate, income, foreign background, single parents with children still living at home, and population per square kilometer) were divided into five numeric classes, with the values in the lowest class being assigned a numerical value of 1, and with those in the highest class being given a value of 5. An example is the division of the median income variable into five classes. This division is based on Statistics Sweden's official classification of income intervals (gross income before tax) of the population aged 20 and over: Quartile 1: 0–163,617 SEK; Quartile 2: 163,618–280,169 SEK; Quartile 3: 280,170–400,577 SEK; and Quartile 4: SEK 400,578 SEK or more [37]. In addition to the four quartile classes, a fifth class has been added for those with an income of more than SEK 500,000 (see Table 1). The lowest income class is assigned a value of 1, the second-lowest a value of 2, and so on. All variables, intermediate descriptions, and classification methods, along with the number of mapped 250 × 250 m grids for each variable and also the motivation of classes and data sources, are presented in Table 1.
2. The variables were then combined into three intermediate indices—family, housing, and economic conditions—by adding the classified values for all variables included in a given index and then dividing by the number of variables. For example, the intermediate index for economic conditions is calculated as follows: the values for the variables education, employment rate, and income were summed, and then divided by 3. The maximum value per mapped 250 × 250 m grid—corresponding to good economic conditions in our model—is therefore 5 ((5 + 5 + 5)/3). The lowest possible value per grid—vulnerable (or poor) economic conditions—is 1 ((1 + 1 + 1)/3). The intermediate indices for housing (segregation) conditions (variable: foreign background) and family conditions (variables: overcrowding—population per km^2; single parents with children still living at home) were calculated in the same way.
3. The final living conditions index was also calculated in the same way: the values of all three intermediate indices were given the same weight and then added and divided by 3. The index values for different levels of living conditions were then classified in a range between 1 and 5. Since the index values are normally distributed, the classification and mapping have been based on standard deviations from the mean value (Figure 3).
4. The mapped living conditions index was then overlaid onto the two police-defined datasets.

All calculations and mapping operations have been performed in ArcGIS pro versions 2.5.0 and 2.6.0.

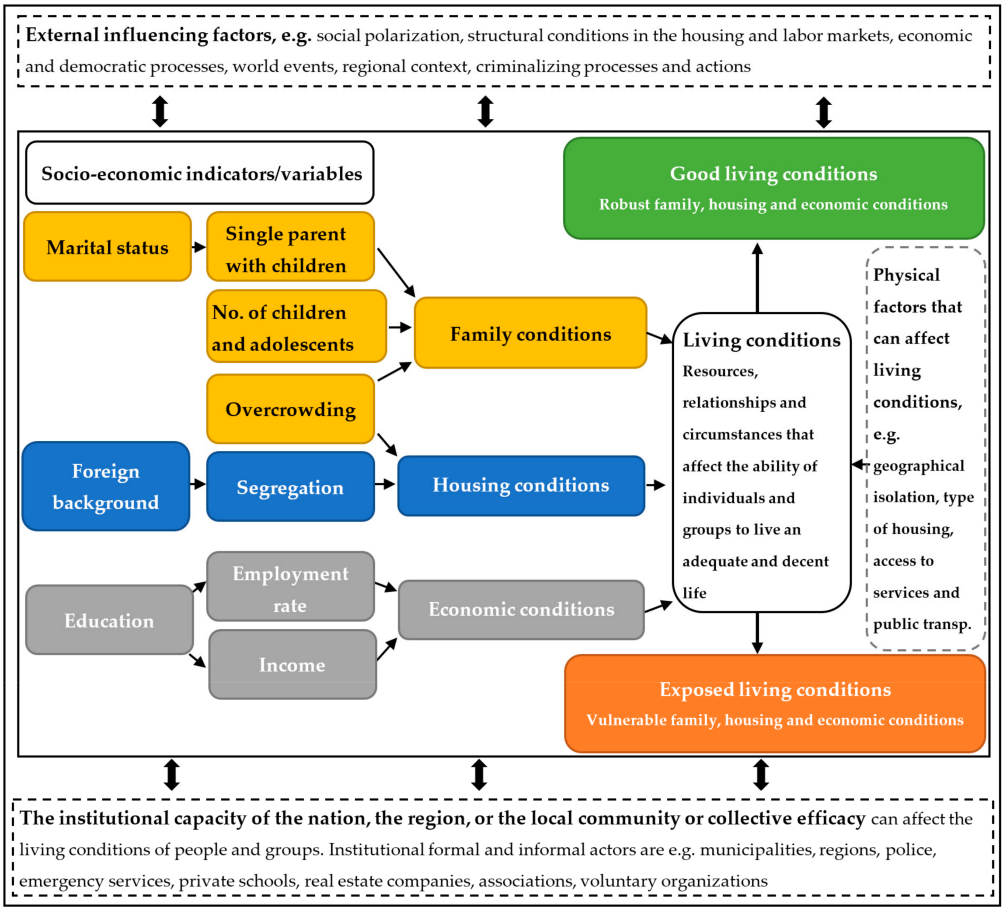


Figure 2. Distributed index values of living conditions across Sweden (mean (M) = 3.84; median (M1) = 3.94; std. dev (SD) = 0.60; number of grids (*n*) = 69,567).

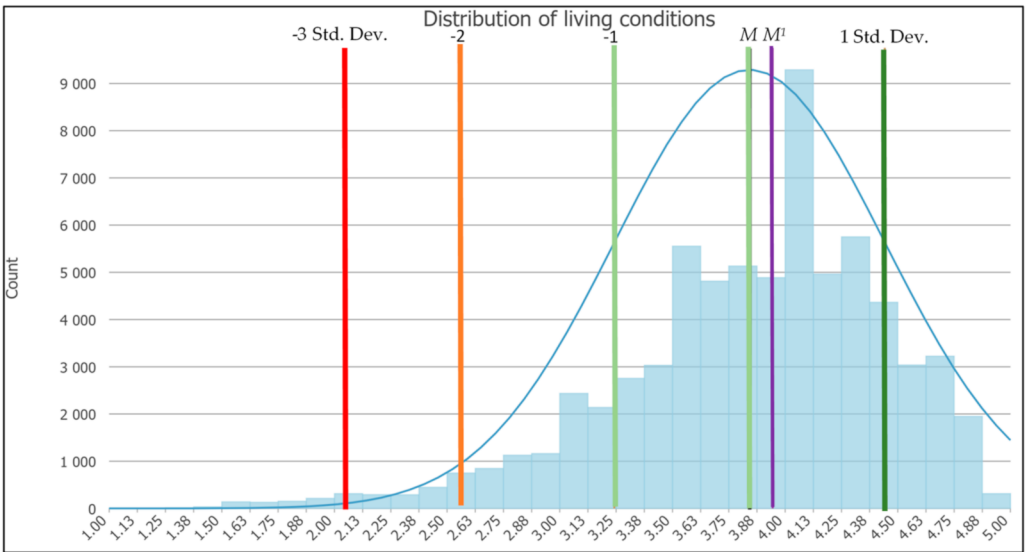


Figure 3. Theoretical and causal model of living conditions in a geographical area. The model also includes physical factors, external factors, and collective efficacy.

Table 1. Intermediate descriptions, classification of variables, classification methods, classes, number of mapped 250 × 250 m grids for each variable, motivation of classes, and source and comments.

Intermediate Description	Variable	Classification Method and Classes	No. of Grids	Motivation of Classes	Source and Comments
Economic conditions	Education—Pre-upper-secondary education (%)	Classification based on mean and standard deviations (normal distribution), rounded to the nearest integer; mean value = 12.7 *Class 1:* 49.1–100% *Class 2*: 23.1–49% *Class 3:* 10.1–23% *Class 4*: 3.1–10% *Class 5:* 0–3%	85,632	The lower the level of education, the greater the risk of economic marginalization.	Statistics Sweden (SCB) Year of collection: 2018
	Employment rate (%)	Classification based on mean and standard deviations (normal distribution), rounded to the nearest integer; mean value = 79.6 *Class 1*: 0–43% *Class 2*: 43.1–59% *Class 3:* 59.1–75% *Class 4*: 75.1–90% *Class 5*: 90–100%	81,672	The lower the employment rate, the greater the risk of economic marginalization.	Statistics Sweden (SCB) Year of collection: 2018
	Income (SEK)	*Quartiles + 1 extra added class;* mean value = 269,995 *Class 1*: 0–163,617 SEK *Class 2*: 163,618–280,169 *Class 3*: 280,170–400,577 *Class 4*: 400,578–500,000 *Class 5 (added)*: over 500,000	94,612	The lower the income, the greater the risk of economic marginalization.	Statistics Sweden Year of collection: 2016 The division is based on Statistics Sweden's official classification of the median income intervals (gross income before tax) of the population aged 20 and over.
Family conditions	Marital status–single parents (%)	Classification based on mean and standard deviations (values not normally distributed), rounded to the nearest integer; mean value = 5.08 *Class 1:* 20.1–100% *Class 2*: 15.1–20% *Class 3*: 8.1–15% *Class 4*: 3.1–8% *Class 5:* 0–3%	97,344	The higher the proportion of single parents with children living at home, the greater the risk of vulnerable family conditions.	Statistics Sweden Year of collection: 2018
	Population per km^2	Classification based on mean and standard deviations (values not normally distributed), rounded to the nearest integer; mean value = 1303 *Class 1*: 8500.1–79,799 *Class 2*: 5000.1–8500 *Class 3:* 2500.1–5000 *Class 4*: 1000.1–2500 *Class 5:* 0–1000	105,613	The higher the population density, the greater the risk of vulnerable family conditions.	Statistics Sweden Year of collection: 2018
Housing conditions (segregation)	Foreign background (%)	Classification based on mean and standard deviations (values not normally distributed), rounded to the nearest integer; mean value = 15.6 *Class 1*: 70.1–100% *Class 2*: 50.1–70% *Class 3:* 25.1–50% *Class 4*: 10.1–25% *Class 5*: 0–10%	108,113	The higher the proportion of the population with a foreign background, the higher the risk of segregation and vulnerable housing conditions.	Statistics Sweden Year of collection: 2018

3. Theory

The operationalization and indexation of living conditions for measurable geographical units are based on the theoretical and causal model presented in Figure 2. Living conditions are, in this context, generally defined as resources, relationships, and circumstances that affect the ability of individuals and groups to live an adequate and decent life [7]. This definition is quite open because living conditions can be difficult to measure holistically. A number of key socio-economic factors are therefore instead used as indicators of living conditions in terms of family, housing, and economic conditions. Many of these variables have a strong basis in theory and are frequently used in research as measurable indicators of vulnerability and deprivation at different geographical scales [10,38].

Family conditions are very much about the care children receive (or do not receive) from their parents or in other relationships [8]. The measurable indicators we see that affect family conditions are marital status, and, particularly if the parent is single and has children still living at home, the number of children and adolescents in different age groups, and the level of overcrowding (yellow boxes in Figure 2). Foreign backgrounds are strongly linked to segregation and spatial differences in housing conditions in Swedish cities (blue boxes). Vulnerable housing conditions are also affected by high levels of overcrowding. Economic conditions can be operationalized using measures focused on income level, degree of education, and the employment rate (gray boxes).

By measuring and mapping these three dimensions of living conditions, different levels of economic marginalization, segregation, and vulnerable family and housing conditions can be identified across a geographical area. When these are, in turn, combined into an index (see Section 2.2), it becomes possible to produce a scale ranging from vulnerable to good living conditions in different geographical areas.

As shown in the theoretical model in Figure 2, there are additional influential dimensions that may be considered as indicators of living conditions. These include, for example, physical factors such as type of housing, the geographical isolation of an area, and access to services and public transport. We have not been able to incorporate these factors, however, due to the lack of national data on the geographical scale employed. Not all dimensions of living conditions can be easily measured, such as external and structural factors. As the model shows, the external and structural factors that exert influence include social polarization, structural conditions in the housing and labor markets, economic and democratic processes, global events with country-level effects, the regional context, and criminalizing processes and actions, such as open drug trafficking and violence against the police and citizens. Another influential dimension that is difficult to measure comprises the institutional capacities of the nation, the region, or the local community, and the collective efficacy of groups [16,39]. Important formal and informal institutional actors behind these capacities include, for example, municipal and regional administrations, the police, emergency services, private schools, real estate companies, associations, and voluntary organizations. Although they are not included as measurable variables in this study, we would recommend that the above-mentioned dimensions should be taken into account in more detailed studies of living conditions in specific geographical areas.

4. Results

The results from the classifications of the intermediate indices (economic and family conditions) and the living conditions index are presented in Table 2. The number of indexed 250 m squares across Sweden has been reduced from the maximum possible of 108,113 to 69,567 due to non-overlapping socio-economic and demographic data. Despite this reduction, the mapping covers over 2000 Swedish urban areas with a population of 200 or more. This is highly relevant, given that 87% of Sweden's population lives in urban areas [40].

Table 2. Classification methods for different indices (economic, family, and living conditions) and the number of mapped 250 × 250 m grids per dataset.

Index	Classification Method	No. of Grids
Economic conditions	Classification based on mean and standard deviations (normal distribution); mean value = 3.29	69,567
Family conditions	Classification based on mean and standard deviations (values are not normally distributed); mean value = 4.16	69,567
Housing conditions (segregation)	Classification based on mean and standard deviations (values are not normally distributed); mean value = 4.08	108,113
Living conditions	Classification based on mean and standard deviations (normal distribution); mean value = 3.84	69,567

The index values for living conditions turn out to be normally distributed across Sweden (Figure 3). These values have been divided and mapped into five classes based on standard deviations, with the class with values less than or equal to (≤) −2.0 standard deviations from the mean value corresponding to areas with vulnerable living conditions. This means that the mapped 250 × 250 m grids with total index values less than or equal to (≤) 2.63 (Figure 3) represent areas with vulnerable living conditions. At least two such areas can be seen on the map in Figure 4. Index values greater than (>) −2.0 standard deviations (>2.63) correspond to neighborhoods with good living conditions, while values of more than 1.0 standard deviation above the mean indicate living conditions that are very good. Areas with good to very good living conditions make up the majority of all mapped grids—for example, the area Brämhult in eastern Borås in Figure 4.

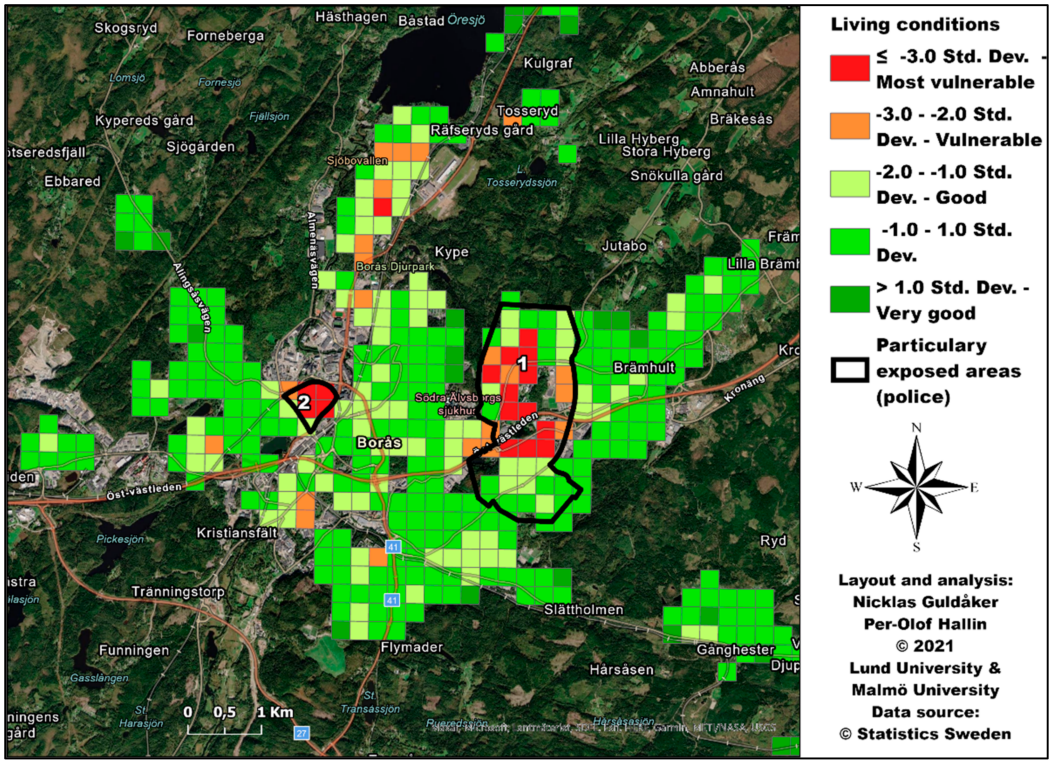


Figure 4. Living conditions and crime-exposed areas in the Swedish city of Borås. The police's assessments of exposed areas are from 2018 to 2019.

The results of the classification and mapping of living conditions show a distinct geographic pattern for the vulnerable and most vulnerable areas (i.e., red and orange areas in Figures 4–7). What is also clear is that these areas largely correspond with the Swedish

Police's own independent assessment of exposed areas. As the map in Figure 4 shows, there is an overlap between the police's assessment and our mapping of living conditions (areas 1 and 2). It is also clear that the area boundaries for the police's assessment of exposed areas based on high levels of perceived criminal activity extend beyond the most socio-economically vulnerable areas. This may be interpreted as indicative of criminal neighborhood effects in areas adjacent to those with vulnerable living conditions, and reduced quality of life [41,42]. Another possibility is that there are issues with the police's method for classifying such areas, meaning that they at times capture much larger areas than they should [25].

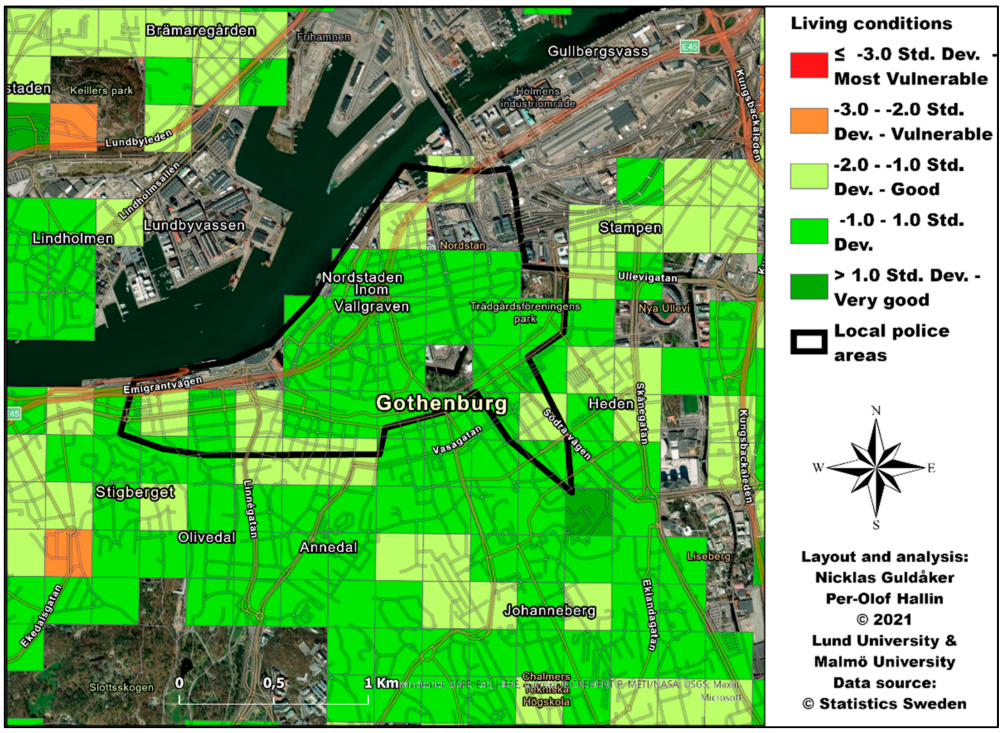


Figure 5. Urban center in Gothenburg. The police's assessments of local police areas are from 2018 to 2019.

Further, the results reveal at least three types of areas that may be important to the police's preventive efforts in urban areas. These are: (1) expected vulnerable areas, where the police's assessment of crime-exposed areas overlaps with area grids characterized by vulnerable living conditions (Figure 4); (2) urban centers that the police have mapped as crime-exposed based on their LPA mapping (Figure 5); and (3) vulnerable grid areas not classified as crime-exposed by the police (Figure 6). The first type has already been presented for Borås (Figure 4), as an example of a Swedish city with neighborhoods with vulnerable living conditions. The second type of area is associated with a classic geographical pattern characterized by high concentrations of crime in urban centers, as in the example of Gothenburg's business and communication center in Figure 5. The black polygon around the urban center of Gothenburg, which represents the area identified as crime-exposed in the police's LPA mapping, relates to outdoor crime and has little to do with the usually good living conditions among the residents of this area. The third category may be important because it may indicate that there are structural conditions present that can lead the area to develop into a problem area. These areas may also be of interest if there are other underlying preventive factors and mechanisms present that are causing the low levels of crime and social unrest, despite the vulnerable socio-economic and structural conditions. Areas of this kind exist in several Swedish cities, such as Västerås, Stockholm, Trollhättan, and Gothenburg. A visual example of such an area—Brickebacken, in the city of Örebro—is presented in Figure 6 (area 1). The map in Figure 6 also shows a risk area

(area 2) and a particularly exposed area (area 3). Areas 2 and 3 have already been defined by the police in accordance with the police's assessment criteria based on socio-economic status, criminal networks, and impacts on the local community.

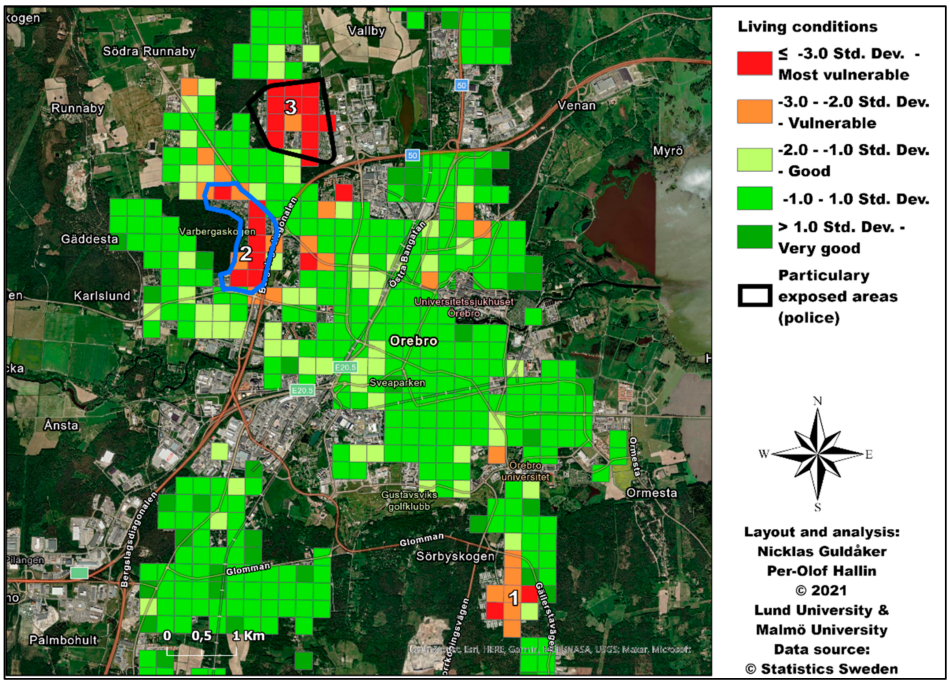


Figure 6. Brickebacken in Örebro (area 1) has vulnerable living conditions, but has not been assessed by the police as an exposed area. The other areas, Varberga (area 2) and Vivalla (area 3), have been assessed as a risk area and a particularly exposed area, respectively. The police's assessments of exposed areas and risk areas are from 2018 to 2019.

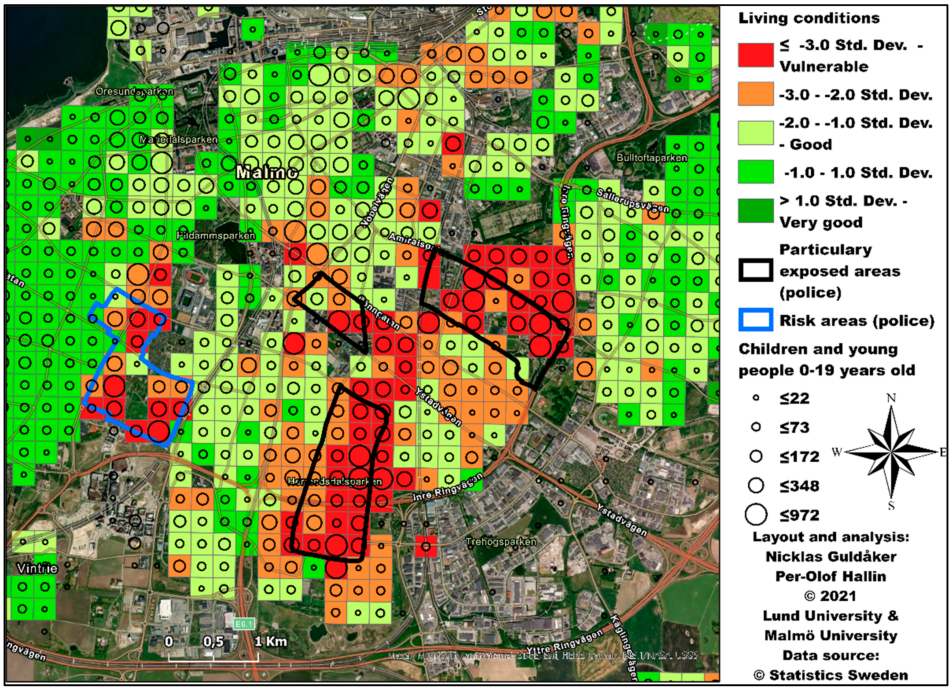


Figure 7. Living conditions, exposed areas (assessed by the police), and varying levels of resident children and young people in Malmö. The police's assessments of exposed areas and risk areas are from 2018 to 2019.

As already indicated, the police's independent mapping of exposed areas largely overlaps with our mapping of vulnerable living conditions. This overlap is notable for particularly exposed areas and risk areas. As illustrated in Table 3, over 61% (801) of the total of 1306 intersecting grids (defined by the police as exposed areas, particularly exposed areas, or risk areas) are characterized by vulnerable living conditions. Around 38% of the intersecting grids are categorized as having good living conditions, and only 0.5% as having very good living conditions. As indicated earlier in the paper, a possible explanation for these latter areas having been classified as exposed by the police assessment may be that they are experiencing neighborhood effects due to the immediate geographic proximity of established criminal territories [41,42]. These findings may also indicate that the police's experience-based and subjective assessments of exposed areas, particularly exposed areas, or risk areas need to be improved.

Table 3. Geographical distribution of living conditions within areas assessed by the police to constitute exposed areas (Total number of intersecting grids = 1306, Total number of all grids = 69,567).

Living Conditions	No. of Intersecting Grids	% of Intersecting Grids	Tot. No. of Grids	% Grids of Total
Vulnerable (red and orange) ≤ -2.0 Std. Dev.	801	61.33	2787	4.01
Good (light green and green) -2.0 to 1.0 Std. Dev.	499	38.21	54,978	79.03
Very good (dark green) >1.0 Std. Dev.	6	0.46	11,802	16.96
Total	1306	100	69,567	100

Moreover, the results show that vulnerable living conditions characterize only 4% (2787) of the total number of 69,567 grids. Of these, about 1% (801) are included in the police's mapping of exposed areas. Viewed in terms of the model presented earlier, and the study's mapping of indexed living conditions, this also means that around 2.9% (1986) of all the mapped grids in Sweden have vulnerable living conditions without the police having defined them as exposed areas. While 61% of the intersecting grids have vulnerable living conditions, only 2.9% of non-intersecting grids do so, indicating that vulnerable living conditions are about 20 times more common in the intersecting grids. Nevertheless, this means that there are many areas that have vulnerable living conditions but have not been classified as crime-exposed areas by the police. This is exemplified by the above-mentioned residential area (1), Brickebacken, in the city of Örebro (Figure 6). Another explanation may be that the police's geographical assessment does not cover all the red and orange grids in an area with vulnerable living conditions (e.g., Varberga, area 2 in Figure 6). Even in this case, there may be reasons to review the geographical boundaries established by the police. There may also be explanations relating to experiences from police operations in places where many crimes have been committed, or to the presence of physical barriers, e.g., roads and complexes of buildings that affect the police's drawing of vulnerable areas.

The map in Figure 7 also elucidates the spatial connection between the mapping of living conditions, the police's assessments of vulnerable areas, and the number of children and young people residing in the area. Large cohorts of young children in vulnerable areas increase the risk of these children being recruited into criminal networks, which can also affect place-based crime patterns involving offenses such as the sale of drugs and violent crime [43]. The results also indicate, however, that large cohorts of children and young people do not automatically lead to an increased risk of crime in certain urban environments, such as more affluent areas with large numbers of families with children (greener areas with large rings). Instead, this risk must be related to other stressor conditions, such as poorer household finances, unemployment, and more vulnerable living and housing conditions due to, for example, overcrowding and large numbers of single-parent families [6]. In this context, other factors may also affect the development of an area, such as the above-mentioned informal and formal capacities of residents, property owners, or other local organizations and authorities.

5. Discussion and Conclusions

The purpose of this paper has been to present and apply a theoretically and methodologically grounded GIS-based model for the measurement and mapping of an index of living conditions in urban residential areas across Sweden. The model is based on previous research identifying variables that are associated with vulnerability and disadvantage [16,19]. Further, the model has been compared and evaluated in relation to the Swedish Police's assessment of crime-exposed areas.

The findings show that the results of the scientific, index-based method and model and those of the experience-based police assessment match to a certain extent. The overlap is relatively good, with 61% of all crime-exposed grids being characterized by vulnerable living conditions.

The results also indicate that there may be several vulnerable areas that have not been included in the police's assessment of crime-exposed areas, but which have vulnerable living conditions that may have a negative effect on the development of crime. Another reason for these not having been included in the police's assessment may be that some areas with vulnerable living conditions have a limited crime problem according to the police's criteria. If this is the case, it represents a positive outcome, and these areas need to be studied in more detail in order to establish which local conditions are restricting the development of crime. A possible way forward is to further develop the model by also including variables that can measure, for example, the institutional capacity of society or the collective efficacy of the local community. The findings also demonstrate that certain crime-exposed areas, e.g., city centers and areas around transportation hubs, cannot be linked to the living conditions of areas' residents.

As a first step towards obtaining practical benefits from our modeling and mapping of living conditions, the Swedish Police have begun to use the results in their work. An initial map of living conditions, named *Strategic Map 1.0*, has been included in the Swedish police's GIS system in order to improve their assessment of vulnerable areas throughout Sweden. This work is also being conducted with the support of several other scientifically based models, perspectives, and working methods, with the aim of preventing crime in vulnerable areas in numerous Swedish cities [25]. The police's list of exposed areas is updated in the context of an annual assessment process, with a number of new areas being added each year, while others are removed from the list. This process is continuous, since crime levels, crime prevention activities, and people's living conditions all change over time.

Despite the initial success of the implementation of *Strategic Map 1.0*, there remains a need to refine and improve the theoretical model, the index, and the method of mapping living conditions. Thus, in addition to improving the accuracy of the police's work in assessing exposed areas, the modeling and mapping of the living conditions index also need to be developed to include more dimensions that affect people's living conditions in the areas in which they live. Additional variables need to be included in the index and evaluated. Variables measuring demographic, socio-economic, health-related, and physical conditions that affect people's living conditions can be added in order to strengthen the reliability of the model and the mapped index [10]. In addition, the theoretical and analytical discussion on areas characterized by vulnerable living conditions and their relationship (or lack of a relationship) with crime exposure needs to be continuously developed and refined. This also applies to future studies, in which factors such as local land use, mobility, and population movements between different areas of the city, in combination with, for example, the routine activity theory, might be employed to analyze and explain trends in crime that are not captured by the living-conditions model. This may also include non-residential areas.

An important part of this work involves continuously validating the index produced at the appropriate scale level (in this study 250 × 250 m grids), conducting sensitivity analyses, and managing the uncertainty inherent in data sources and in the development of an index based on multiple variables [10,44]. The weighting of index variables on the

basis of different methods (e.g., equal or unequal weighting based on expert opinion or empirical tests) should also be reviewed [10,45]. Further, the competence of the police needs to be improved in order to facilitate the assimilation of more scientifically based methods in their preventive and operational crime-related work. In addition to supporting the police's preventive crime work, we would argue that the model and the mapping of living conditions (as an index) would also constitute support to the work of other societal actors in vulnerable areas. Such actors include municipalities, emergency services, real estate companies, and other regional actors or researchers who work with community planning, security, and safety in socially disadvantaged urban and rural areas. For these purposes, future studies should also include the mapping, analysis, and evaluation of living conditions over time.

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