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CPTED-Driven Territorial Risk Scoring

Crime Prevention Through Environmental Design applied to spatial risk assessment

Bicocca Academy

CRISP Interuniversity Research Centre for Public Services

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ABSTRACT

Project overview and reference context

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Theft risk assessment in the residential context

The project proposes a data-driven approach to assessing theft risk within the Home and Family Insurance product: Casa Serena, based on the hypothesis that the urban context surrounding a residence significantly influences the likelihood of criminal events.

Traditionally, many environmental features related to safety are described qualitatively. The goal is to make these features measurable by transforming them into quantitative variables for insurance processes such as pricing, underwriting, and prevention.

The theoretical reference is CPTED (Crime Prevention Through Environmental Design), used not as a design tool but as a conceptual framework for feature selection.

Project Objectives

- **Quantitative Variables**
  From Qualitative to Measurable
- **Insurance Processes**
  Pricing, Underwriting, Prevention
- **CPTED Framework**
  Feature Selection Guidance

The Role of the Territorial Context in the Home Insurance Sector

In the Home insurance sector, and particularly for Theft coverage, the risk depends not only on the characteristics of the property or the policyholder but also on the surrounding territorial context.

In insurance practice, the territory is often represented using aggregated proxies such as municipality or postal code. These indicators are easy to manage but lose local information, flattening significant differences.

Contextual Factors Affecting Risk::

- Building Density
- Accessibility
- Presence of Activities
- Level of Informal Surveillance

Current Consequences::

Less accurate pricing

Challenges in portfolio segmentation

Limited targeted prevention capabilities

Residence A — **Similar Features**

Secure, Supervised Environment

High Visibility | Good Maintenance

Low risk

VS

Residencee B — **Similar Features**

Isolated, degraded context — High risk

Low visibility | Easy escape routes

Two identical dwellings can have opposite risk profiles due to the urban context.

CPTED

Crime Prevention Through Environmental Design

CPTED

Crime Prevention Through Environmental Design

CPTEDHistoricalContext

The Crime Prevention Through Environmental Design (CPTED)

It is an approach developed between the 60s and 70s that studies how the configuration of the built environment influences opportunities for criminal behavior.

Starting from the contributions of Jane Jacobs and Oscar Newman's Defensible Space Theory, CPTED is formalized by C. Ray Jeffery as a prevention strategy that acts on the physical context rather than on the individual.

The key principle is that readable, surveillable and well-maintained spaces reduce opportunities for opportunistic crimes, favoring the natural and informal control of space.

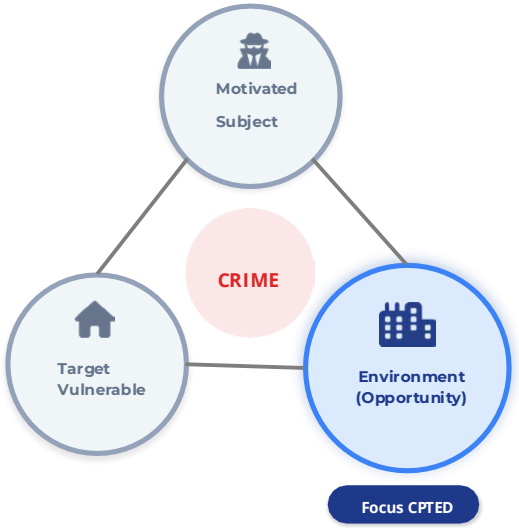
CPTED is a multidisciplinary approach that studies how the built environment influences human behavior and criminal opportunities.

The Crime Triangle:

The idea is that crime emerges from interaction between:

- A motivated subject
- A vulnerable target
- An environment that offers opportunities

CPTED acts on the third element: the environment.



Objectives in the project:

Not used to "design", but as a theoretical grid to:
Identify the relevant environmental dimensions
Select the observable variables
Interpreting the results

GENERALI

CPTED

Crime Prevention Through Environmental Design

Classical principles of CPTED - *Key guidelines for environmental prevention*

Natural Surveillance

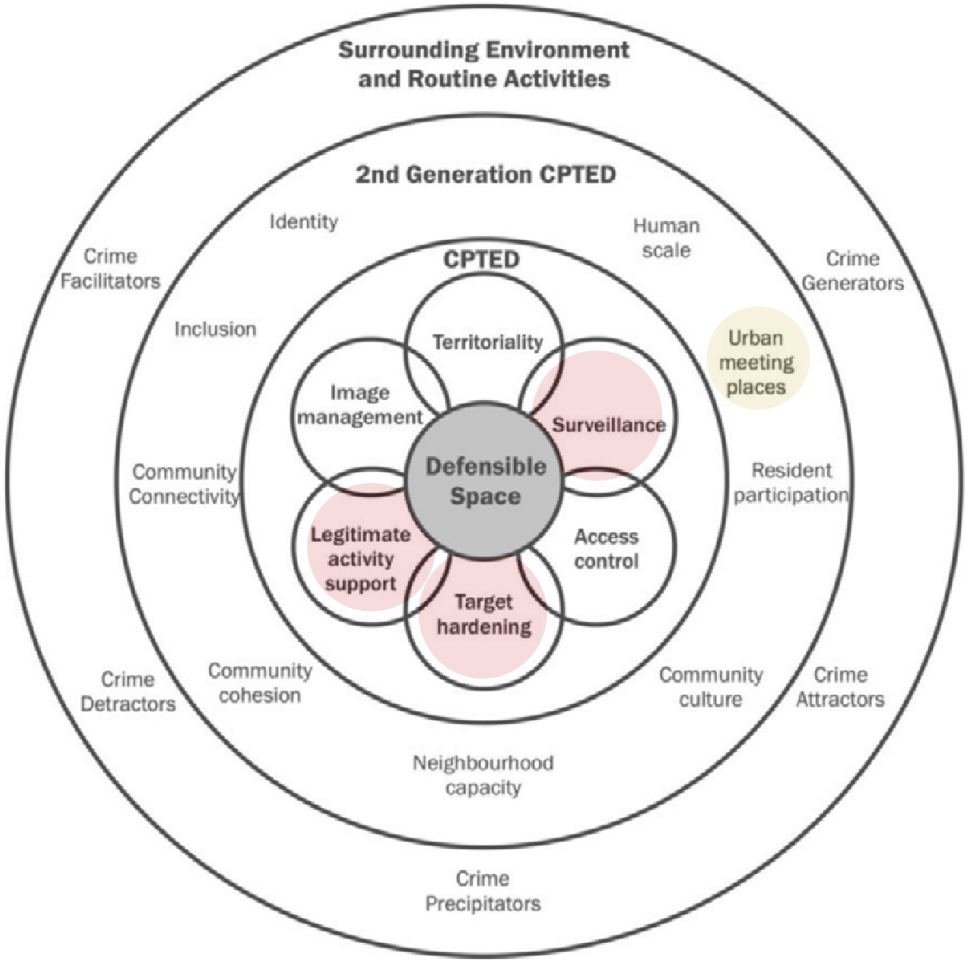
Ability of a space to be observed spontaneously. Visibility increases the risk perceived by the perpetrator and deters illegal behavior.

Activity Support

Presence of legitimate people, services and activities that generate informal control ("eyes on the road") reducing isolated areas.

Target Hardening

Physical and mechanical measures that increase the effort required for the intrusion (alarms, railings, security locks).



Territorial Reinforcement

Clarity of the boundaries between public, semi-public and private space. It defines ownership and encourages legitimate users to defend the space.

Acess Control

It's all about ease of entry, exit, and escape. A very permeable road network and uncontrolled access increase criminal opportunities.

Image and Maintenance

Well-kept spaces communicate active social control. Degradation (broken window theory) signals an absence of control and tolerance for disorder.

GENERALI

CPTED

Crime Prevention Through Environmental Design

Feature Engineering

Each CPTED principle is translated into measurable features for quantitative analysis.

Surveillance natural

- Building density
- Relationship between buil and open space
- Presence and distribution of vegetation

Access Control

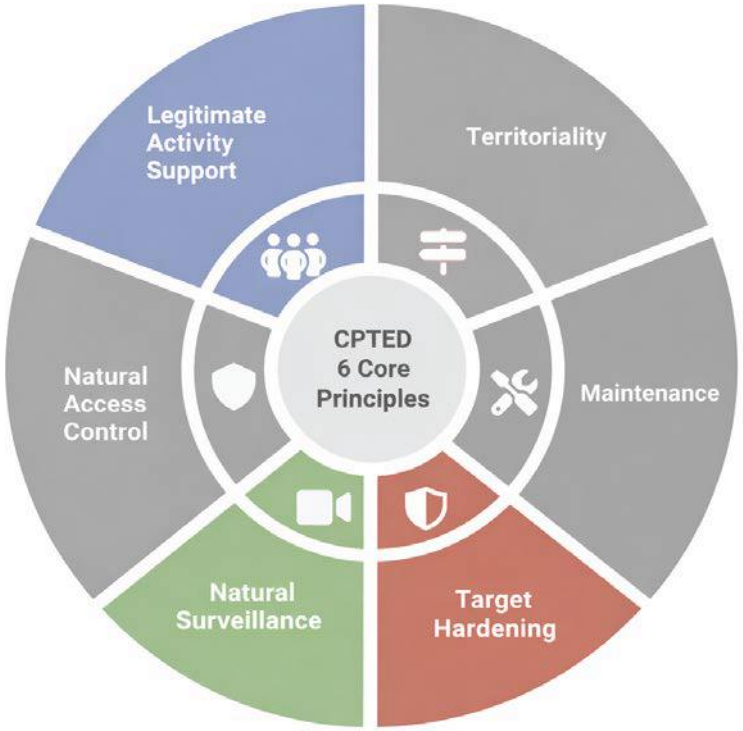
- Road density
- Number of intersections
- Topological complexity of the network

Activity Support

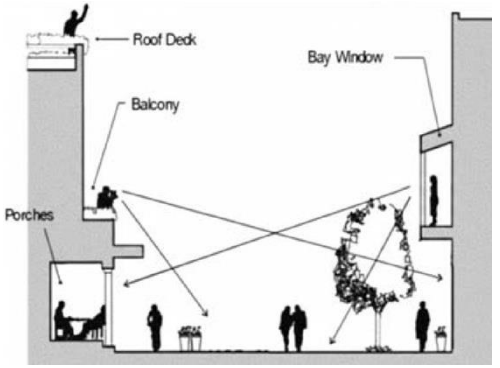
- Presence of services
- Points of interest (POI)

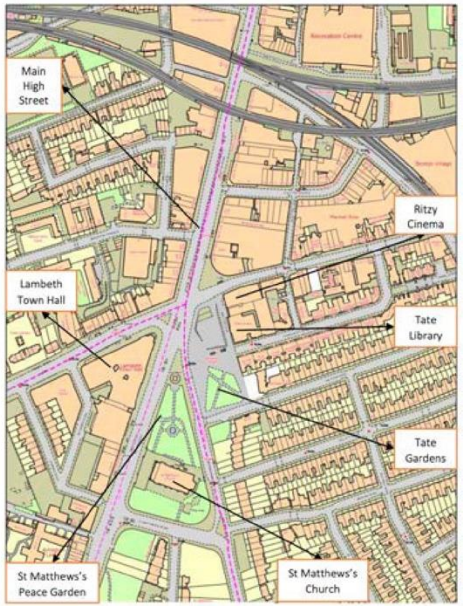
Target Hardening

- Existing insurance data (presence of alarms)



From a qualitative concept ("visible area") to a quantitative metric ("% vegetation cover", "density of road junctions") that can be integrated into risk models.





PIPELINE

Prototype Architecture

Prototype pipeline

The prototype is intended to automate the collection of environmental information around each home, overcoming
the limits of manual evaluation. The operational flow follows a sequential, automated pipeline that transforms a raw address into a set of structured risk variables.

Automatic extraction

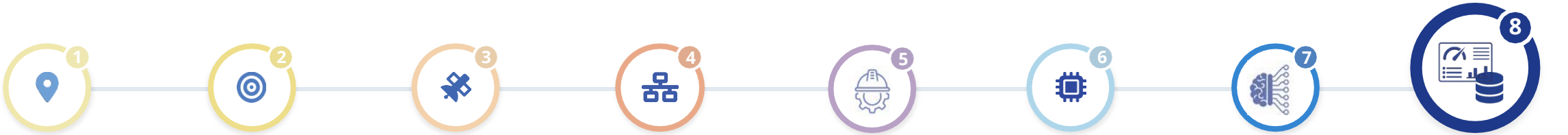
- Spatial and geometric data
- Visual characteristics of the territory
- Network topology metrics

Structured Output

- Structured and homogeneous dataset
- Comparability between different contexts
- No manual intervention required

- **Ripetibile**
- **Scalabile**
- **Automatizzabile**

DATA-DRIVEN APPROACH
Transformation of the territory into analyzable data: scalability of the evaluation process on extensive insurance portfolios.



Geocode
Conversion of the input address to coordinates (the-titude, longitude).

Spatial buffers
Defining the Area of interest around the point (e.g. radius 300m).

Image Acquisition
Automatic download of homogeneous satellite tiles for the selected area.

Geographic Data
Extraction of road network and POIs from OpenStreetMap (OSMnx).

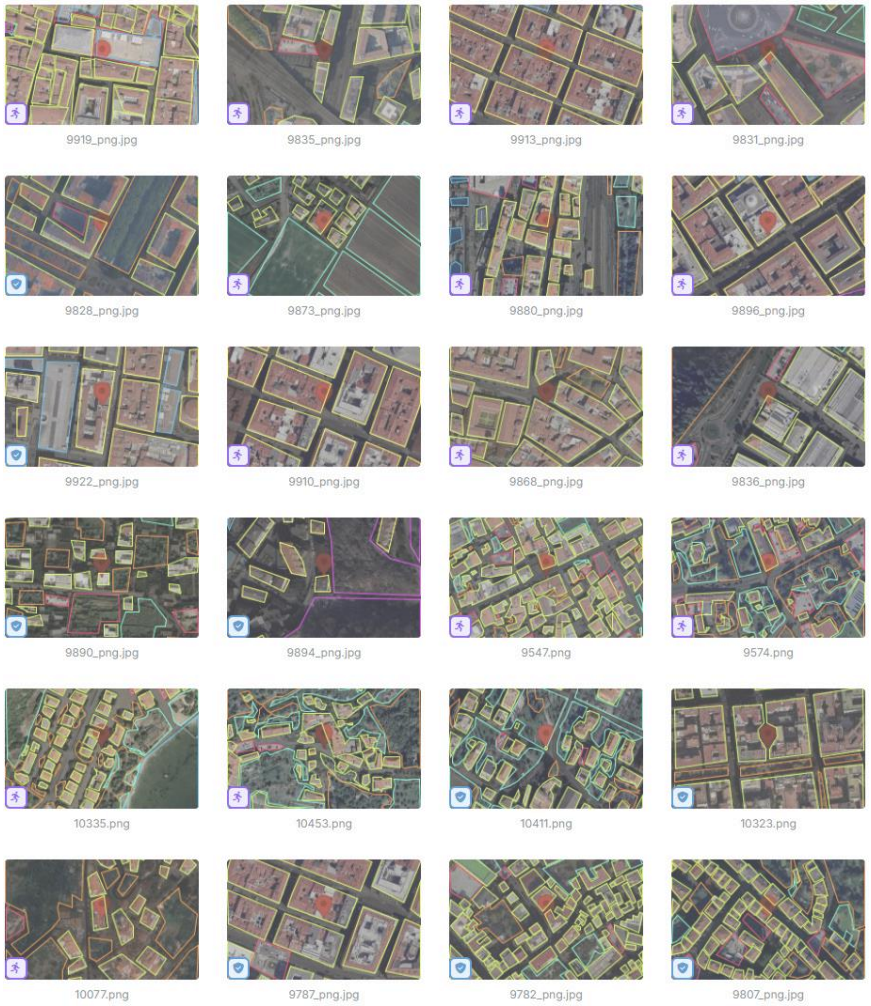
Feature Engineering CPTED
Translation of CPTED principles into quantitative indicators comparable between habitations.

Computer Vision
Segmentation of satellite images

Scoring & Modeling
Use of Ma-chine Learning models (Adaboost) to combine territorial and environmental features.

Dataset & Dashboard
Integration of all info into a single structured record.

Computer Vision: from images to features



High building density

Prevalence of built area with little vegetation. High potential natural surveillance.

Balanced mix

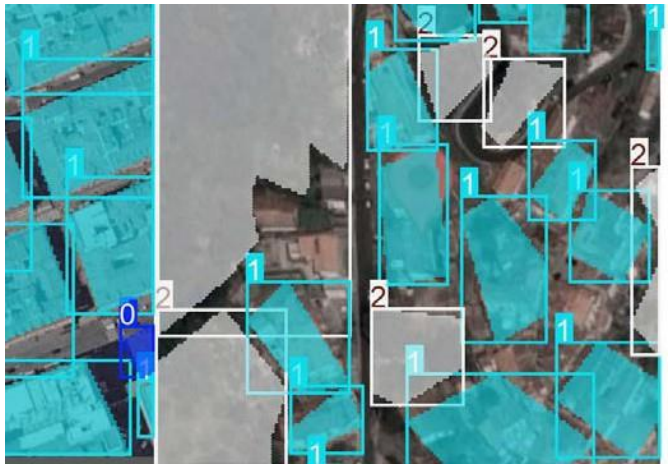
Balancing buildings, private gardens and roads. Typical suburban context with defined territorial control.

Spatial fragmentation

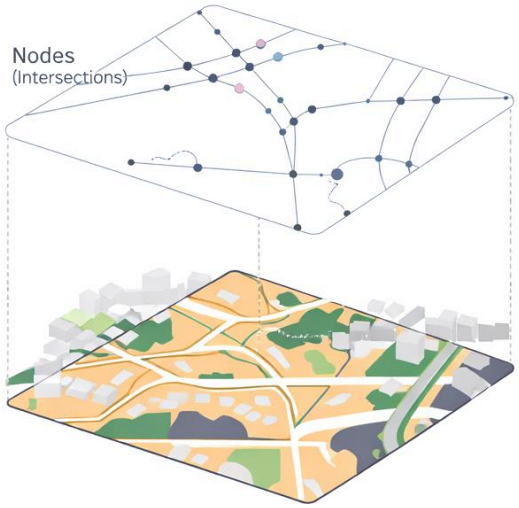
Large unmanaged open spaces, scattered buildings and infrastructure. Low natural surveillance and uncertain boundaries.

roboflow

COLOR	CLASS NAME	COUNT
	area_open	880
	built	3756
	vegetation_high	416
	vegetation_low	680
	water	23



Road network as graph and metrics



Points of interest - POI

- **Scuole** / Università
- **Ospedale** / Farmacia
- **Aree Commerciali**
- **Vita Notturna**
- Forze dell'Ordine

Topological Analysis & Accessibility

The road network is modeled as a mathematical graph where intersections are nodes and roads are arcs. This makes it possible to calculate objective metrics on the permeability and accessibility of the area, crucial factors for the theory of criminal opportunities.

Intersection Density
Local complexity

Road Segments
Infrastructure volume

Average Degree Knots
Connectivity

Permeability
Ease of escape

Space Technology Stack

OSMnx	NetworkX	GeoPandas	PyProj
Data Extraction	Graph Analysis	Geometry	Projections

Loss Context Analysis

Analisi Contesto Sinistro – Assicurazione Casa

Profilo Cliente

- Cliente: **9577**
- Prodotto: **Casa Serena**
- Sinistro: **Furto**
- Allarme: **Presente**

Servizi nelle Vicinanze (≤ 500 m)

- **Scuole** / Università
- **Ospedale** / Farmacia
- **Aree Commerciali**
- **Vita Notturna**
- Forze dell'Ordine

Contesto Territoriale (500 m)

- **68,7%** Edificato
- **9,1%** Area Aperta

Accessibilità & Rete Stradale

- Densità: **Alta** (218 nodi/km²)
- Collegamenti: **2,7 in media**

Lettura Assicurativa

- *Area urbana **densamente edificata**, ben servita e facilmente accessibile.*
- ***Assenza di presidi di sicurezza pubblica** nel raggio immediato.*
- ***Sistema di allarme presente** come fattore mitigante.*

Risk Exploration Interface| STREAMLIT APP

Assicurazioni Generali — Risk Assessment KPIs

Inserisci l'indirizzo per stimare il rischio e visualizzare la heatmap dei crimini.

Dati dell'abitazione

Via / Piazza	Numero civico	CAP	Città
Corso Buenos Aires	23	20124	Milano

Metri quadrati: 70

Sistema di allarme: Sì / No

Indirizzo completo: Corso Buenos Aires, 23, Milano

Vista satellitare dell'abitazione

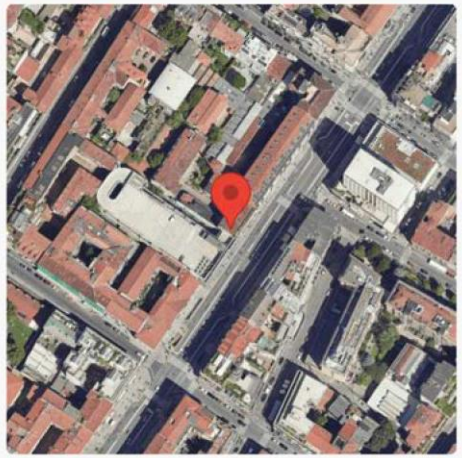


Immagine satellitare

Territorial Features

Feature	Valore (%)
Edifici	50.80
Vegetazione Alta	4.18
Spazi Pubblici	8.67

Street Features

Feature	Valore
Node Density (per km²)	286.48
Average Degree	3.12
Primary Road Ratio	0.0

Points of Interest

Feature	Valore
School / University	Yes
Security Structure Nearby	Police, Fire Station
Nightlife	Yes
Train / Metro Station	Yes

Valutazione rischio furto

RISCHIO BASSO DI FURTO

Assicurazioni Generali — Risk Assessment KPIs

Inserisci l'indirizzo per stimare il rischio e visualizzare la heatmap dei crimini.

Dati dell'abitazione

Via / Piazza	Numero civico	CAP	Città
Corso Italia	97	15040	Frassineto

Metri quadrati: 70

Sistema di allarme: Sì / No

Indirizzo completo: Corso Italia, 97, Frassineto

Vista satellitare dell'abitazione

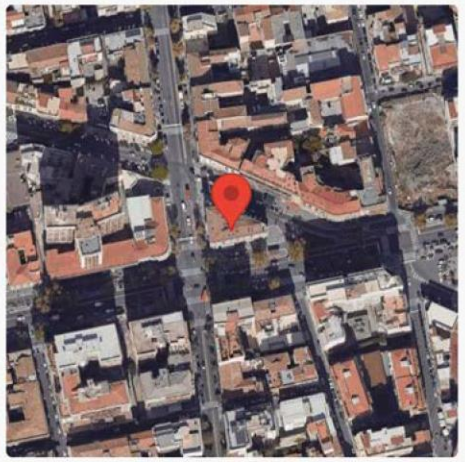


Immagine satellitare

Territorial Features

Feature	Valore (%)
Edifici	53.15
Vegetazione Alta	0.32
Spazi Pubblici	20.60

Street Features

Feature	Valore
Node Density (per km²)	374.33
Average Degree	3.14
Primary Road Ratio	0.2

Points of Interest

Feature	Valore
School / University	Yes
Security Structure Nearby	Police, Carabinieri
Nightlife	No
Train / Metro Station	Yes

Valutazione rischio furto

RISCHIO BASSO DI FURTO

RISK ASSESSMENT KPIs

Quantitative KPIs for Territorial Risk Evaluation

ESTIMATED IMPLEMENTATION COSTS

Cost Structure and Economic Feasibility
for the Insurance Company

Risk Assessment KPI

Strategic Objective

Define KPIs capable of linking the environmental characteristics of the territory (CPTED) to the technical performance of the Theft guarantee. Defined as tools for reading, comparing and validating the impact of the context ex-post, not predictive point estimates.

Loss Ratio (S/P)

Synthetic indicator of technical sustainability of the portfolio (Claims / Premiums).

VALUE PER COMPANY

Even minimal reductions in the loss ratio (-1% / -2%), if applied to large portfolios, generate millions of euros in technical savings.

Probability of Claims

Measure risk exposure independently by the insured value.

CPTED SENSITIVITY

Strongly related to accessibility, urban permeability and natural surveillance.

Severity Media

Average cost per single claim event.

ENVIRONMENTAL FACTORS

Affected by isolation, reduced visibility (inter-wind times) and ease of escape.

Expected Risk Cost

Expected cost of risk (Frequency × Severity).

FUNCTION

Bridge metric between territorial characteristics and pricing/underwriting processes.

PROCESSO DI VALORE

Feature CPTED

↓

KPI Risk Assessment

↓

DECISION
Pricing • Underwriting • Prevenzione

VALIDATION TOOL

Comparison: Benchmark between insurance performance in different urban contexts.

Consistency: Verification of alignment between the risk estimated by the model and observed historical risk.

Utility: Ex-post measurement of the information value of feature CPTED.

ESTIMATED COSTS

Cost structure

The implementation of the CPTED-driven prototype as an industrial pro-of-value requires an initial investment in the valendously focused on skills, rather than on the technological infrastructure.

This is consistent with the literature and current practice in:

Geospatial Risk Analysis
Computer vision applied to the insurance sector Advanced analysis to support underwriting

In these areas, the dominant cost is the skilled human labor needed for high value-added activities such as feature engineering, validation, and model governance.

Driver di Costo

Human Capital
Primary Investment

Tech Infrastructure
Secondary Cost

Added value

ESTIMATED COSTS

Estimate POV (Proof of Value)

ROLE	FTE	RAL ANNUAL	PARTIAL	ACTIVITY DESCRIPTION
Project Manager	**0,5**	60k–80k	**30k–40k**	Roadmap, deliverables; technical-business coordination; cost/FTE/risk monitoring.
Data Scientist / Data Engineer	**1,5**	50k–70k	**75k–105k**	Insurance data integration + KPIs; ETL; modeling/statistics and ML; explainability and validation.
ML Engineer	**0,5**	50k–70k	**25k–35k**	Pipeline dati/modelli; MLOps e deployability; test/monitoring.
Computer Vision Support	**1,0**	30k–50k	**30k–50k**	Satellite imagery dataset; fine-tuning pre-trained models; quality check output.
		HUMAN RESOURCES SUBTOTAL	**160k–230k**	
		TOTAL HR (+35% BUSINESS CHARGES)	**216k–310k**	

Infrastructure and Services

Cloud + API geospazial + CV tooling + MLOps + security/compliance

Cloud compute & storage	25k–45k	MLOps & orchestration	4k–10k
Google Maps Platform	5k–15k	Security & compliance	3k–6k
Roboflow	3k–6k		
TOTAL INFRASTRUCTURE			**40k–80k**

TOTAL POV (12 MONTHS)

256k – 390k

How the CPTED model generates economic value

The value of the project does not lie in the timely prediction of crime, but in the incremental improvement of decisions already along the insurance chain. The central economic reference is the loss ratio of the theft guarantee, a technical metric that summarizes the balance between premiums and claims.

1. Direct connection to insurance data

The dataset in stock allows to:

Evaluate and reduce loss ratio for single housing or cluster

Pair to each remark a set of featuresCPTED and improveUnderwriting

Compare urban contexts different for the same product

> The model: does not "predict crime", but explains observed differences in technical performance. This makes the benefit measurable ex-post, not just theoretical.

2. Where it spawns concretely the benefit

Territorial risk micro-segmentation

Pricing more consistent with real exposure

Support for targeted prevention strategies

Incremental Value

Value comes from better decision applied many times his **large Volumes.**

Accurate Pricing

Segmentation

Prevention

Fairness

ROI

Measurable & Scalable

FUTURE DEVELOPMENTS

FUTURE DEVELOPMENTS

Comprehensive and industrializable evaluation

Evolve the prototype towards a street-level CPTED analysis, scaling down the building and enriching feature engineering on the dimensions of visibility, access and control of the space, with integration into pricing, underwriting and prevention processes.

1. REFINEMENT (STREET-LEVEL)

- **Street View:** to capture elements not visible from satellite
- **Surveillance:** blind fronts, visual occlusions
- **Access Control:** Alleys, Side Passages, Escape Ease
- **Territorial reinforcement:** public/private boundaries
- **Image:** physical degradation, disorder, abandonment
- **Target hardening:** grilles, visible security

2. DATASET INTEGRATION

- **MineCrime (API):** crime analysis platform with API for access to geo-referenced indicators on criminal phenomena
- **ISTAT:** integrations of crime datasets
- **Open Data:** public lighting, maintenance
- **Area fact-finding surveys:** structured interviews with local stakeholders

Complementary layers (enrichment) to policy data

3. SECOND GENERATION CPTED

- **Socio-urban dimensions:** vitality, spaces, functional mix
- **Social capital:** active presence of residents, informal control, sense of Membership

4. INFRASTRUCTURE DEVELOPMENTS

- **Increased image datasets and geographic coverage**
- **Multi-scale analysis of the immediate surroundings and the proximity context**
- **Computer Vision pipeline with human supervision for quality control and**
- **Mitigation of bias**
- **Data Governance: feature versioning and full traceability of data and of evaluations**

FINAL VALUE

Construction of an explainable CPTED score, composed of interpretable sub-indicators, which can be used to improve risk selection, prevention and personalization of the offer.

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