The CRE equivalent of Zestimate: Combining machine learning and spatial modelling to mine big data

Jun Chen
Senior Director, Research, Moody’s Analytics

Wenjing Wang
Director, Research, Moody’s Analytics
Jun Chen
Senior Director - Research
Moody's Analytics

Wenjing Wang
Director - Research
Moody's Analytics
Agenda

1. Real Estate Valuation Overview
2. Comparable Properties and Leases
3. Rent Prediction and Property Valuation
4. Key Takeaways
5. Questions & Answers
1

Real Estate Valuation Overview
Real Estate Valuation Overview

Residential
Comparable Homes
Homes with location proximity and attribute similarity

$995,000
2 bd | 2 ba | 1,175 sq ft
993 Dolores St, San Francisco, CA 94110
- For sale
- Estimate: $1,295,000
- View Details
Est. payment: $4,986/mo
- Get pre-qualified

Contact Agent
Take a Tour

Overview

993 Dolores at 23rd street is an all-new 2-Bed 2-Bath Garden Unit that was just added to a classic Mission Dolores Edwardian. Access to the shared back yard is through a floor to ceiling folding glass NanaWall, a full-size in-unit Washer/Dryer is included, heat is through a building-wide radiant system, there is shared bike storage, access to the unit is at the ground floor, no stairs to climb, there’s a private side patio off the kitchen, sqft measurement is approx 1,175

Read more
Real Estate Valuation Overview

Real Estate Appraisal Process

Sales Comparison Approach

Comps

- Sales comps
  - Location
  - Similar attributes

Adjustments

- Property attributes
  - Size
  - Condition
  - Amenities
  - ……

Appraised Value
Commercial Real Estate Valuation

Biggest challenge: Data!!!

Commonly used approaches
- Cost approach
- Income approach
- Market approach (sales comparison)

Big data and AI Technology

AI-powered Automated Valuation Model (AVM)

Combined to address data issues
Companies Using AI for CRE Valuation

“GeoPhy’s automated valuation model (AVM) provides that much-needed innovation with enterprise-grade, AI-powered insight into the value, and value drivers of commercial real estate assets.”

“Skyline AI partners with leading commercial real estate firms to establish next-generation investment vehicles augmented by artificial intelligence.”

“Built on a highly scalable and resilient next-generation cloud infrastructure, our intelligent models with self-improving Machine Learning capabilities and deep learning algorithms, deliver diverse aspects of properties across the nation.”

“We use machine learning on dozens of disparate data sources to build the Standalone Value….We offer this information to property owners for free to help owners better understand their property values and sell for a premium to market valuation.”
Big Data

- Economic data
  - Business activities
  - Property records
  - Crime data
  - Transportation
  - Amenities
  - Social media
  - Environmental data

- Moody's Analytics Network
  - CMM
  - Data Alliance
  - Econ Data
  - CMBS
  - REIS
  - COMPSTAK
  - MOODY'S ANALYTICS

- Public Data & Data Vendors
  - US Department of Commerce
  - Bureau of the Census
  - REIS
  - CMBS
  - Data Alliance
  - Econ Data

- CMBS
- Lease
- Property
- Loan
- Location
- Market
- Risk
Use Big Data to Help “Small” Data

Office Transactions vs. New leases of San Francisco in May, 2017

Sales Transactions

Valuation

Rent

MOODY’S ANALYTICS

CRE AVM: Combining Machine Learning and Spatial Modeling, Nov 2019
Comparable Properties and Leases
Comparable Properties and Leases
Commercial

**Comps Review**

**405 Howard Street, San Francisco, CA 94105**

- **Floor**: Comparable Properties
- **Name**: Nearest Properties

**Inclusion Options**

- Rent Comps
- Sales Comps
- New Construction Comps
- Investment Analyst

Add Your Own Comp

View: Comparable Properties Nearest Properties

Map showing property locations.
Comparable Properties and Leases
Commercial

**k-nearest neighbors (k-NN) algorithm**

Intuitive and easy-to-implement supervised machine learning algorithm.
## Comparable Properties and Leases

### Optimal Number of Comps: National or Local?

<table>
<thead>
<tr>
<th>City</th>
<th>Optimal Number of Comparable Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>6</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>6</td>
</tr>
<tr>
<td>Washington, D.C.</td>
<td>5</td>
</tr>
<tr>
<td>New York</td>
<td>7</td>
</tr>
<tr>
<td>San Francisco</td>
<td>5</td>
</tr>
<tr>
<td>San Diego</td>
<td>6</td>
</tr>
<tr>
<td>Boston</td>
<td>5</td>
</tr>
<tr>
<td>Orange County</td>
<td>7</td>
</tr>
<tr>
<td>San Jose</td>
<td>3</td>
</tr>
<tr>
<td>Chicago</td>
<td>5</td>
</tr>
<tr>
<td>Oakland</td>
<td>5</td>
</tr>
<tr>
<td>Atlanta</td>
<td>9</td>
</tr>
<tr>
<td>Sacramento</td>
<td>9</td>
</tr>
<tr>
<td>Dallas</td>
<td>7</td>
</tr>
<tr>
<td>Denver</td>
<td>6</td>
</tr>
<tr>
<td>Phoenix</td>
<td>7</td>
</tr>
</tbody>
</table>

### Median Absolute Error Difference (National K = 6 vs. MSA-specific K)

- Los Angeles: 6%
- Washington, D.C.: 4%
- San Francisco: 2%
- San Diego: 0%
- Boston: 0%
- Orange County: 0%
- San Jose: 0%
- Chicago: 0%
- Oakland: 0%
- Atlanta: 9%
- Sacramento: 9%
- Dallas: 0%
- Denver: 0%
- Phoenix: 0%
Feature Importance

Location is the most important feature

Location
Building Size
Building Age

Location
Building Size
Building Age

Los Angeles
Washington, D.C.
New York
Boston
Chicago
Comparable Property and Leases

San Francisco

- 1 Maritime Plaza
- 600 Montgomery Street
- 1 Bush Street
- 425 Market Street
- 525 Market Street
- 100 1st Street
- 345 Spear Street
Rent Prediction and Property Valuation
Rent Prediction and Property Valuation

Structure of Rent Prediction Model

Comparable Properties → Rents of Comparable Properties → Rent Model → Lease Attributes

Commercial LocationScore™

- Economic Prosperity
- Business Vitality
- Spatial Demand
- Amenities
- Transportation
- Safety
## Rent Prediction Model

### Out-of-sample Performance (Median Absolute Error)

<table>
<thead>
<tr>
<th></th>
<th>New York</th>
<th>Los Angeles</th>
<th>Washington, D.C.</th>
<th>San Francisco</th>
<th>Chicago</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear Model</td>
<td>17.2%</td>
<td>15.6%</td>
<td>13.2%</td>
<td>13.3%</td>
<td>13.8%</td>
</tr>
<tr>
<td>Gradient Boosting</td>
<td>12.1%</td>
<td>9.9%</td>
<td>8.9%</td>
<td>10.5%</td>
<td>11.1%</td>
</tr>
</tbody>
</table>

### Model Performance

- **Commercial Location Score**: New York > Los Angeles > Washington, D.C. > San Francisco > Chicago
- **Building Size**: New York > Los Angeles > Chicago > San Francisco > Washington, D.C.
- **Comparables**: New York > Los Angeles > Washington, D.C. > San Francisco > Chicago
- **Building Age**: New York > Los Angeles > Washington, D.C. > San Francisco > Chicago
- **Lease Size**: New York > Los Angeles > Chicago > San Francisco > Washington, D.C.
- **Work Value**: New York > Los Angeles > Washington, D.C. > San Francisco > Chicago
- **Sublease**: New York > Los Angeles > Washington, D.C. > San Francisco > Chicago
- **Free Rent Period**: New York > Los Angeles > Washington, D.C. > San Francisco > Chicago
- **Full Service**: New York > Los Angeles > Washington, D.C. > San Francisco > Chicago
Gradient Boosting Algorithm

» The algorithm creates an ensemble of regression trees
  – Each tree is dependent on prior trees
  – It learns by fitting the residuals of the trees that preceded it
Embarcadero West – San Francisco

Location:
- 275 Battery Street

Property Type:
- Class A office

Architect:
- John Portman

Year Built:
- 1989 (2011 renovation)

Size:
- 30 floors; 475k sqft

Other:
- Part of Embarcadero Center

Vacant Space:
- Space size: 9,630
- Full service
- Work value: $10/sqft
- Free rent: 2 months
Embarcadero West

Initial estimate ($58.32)
- Rent comps
- Commercial Location Score
  - Economic prosperity
  - Business vitality
  - Spatial demand
  - Amenity
  - Transportation
  - Safety

Adjustments (±)
- Initial Estimate: $58.3
- Property Size: +$6.7
- Property Age: +$10.5
- Space Size: -$8.1
- Full Service: +$2.8
- Work Value: +$0.8
- Free Rent Period: +$0.1

Estimated rent ($70.9)

- Another lease:
  - Same building
  - Same month
  - Different lease terms

Estimated rent: $76.2
Actual rent: $74

Actual rent: $71.0
Office Rent Prediction in Multiple MSAs
Other Property Types

Industrial

- 9.36 $/sqft
- 9.0 $/sqft
- 7.2 $/sqft

- 7.88 $/sqft

14425 Clark Avenue, City Of Industry, CA 91745

Retail

- 30.0 $/sqft
- 22.32 $/sqft

- 21.5 $/sqft

- 27.96 $/sqft

- 34.47 $/sqft

888 South Figueroa Street, Los Angeles, CA 90017
Rent Prediction and Property Valuation
Rent Prediction Demo
Rent Prediction and Property Valuation
Leveraging Existing Moody’s Analytics CRE Network

Model

Rent

Commercial Property Performance Model (CPPM)

Cash Flow

NOI

Vacancy

DCF

Value

AVM

Capitalization Rate Data

REIS

Real Estate Solutions by Moody’s Analytics

CRE AVM: Combining Machine Learning and Spatial Modeling, Nov 2019
Rent Prediction and Property Valuation

Example Use Cases

**Appraisers**
- Augment valuation process

**Brokers**
- Brokerage for CRE leases
- Brokerage for CRE sales

**Investors**
- Pinpoint Investment opportunities
- Portfolio diversification

**Lenders**
- Loan underwriting
- Risk monitoring
Key Takeaways
Key Takeaways

» Most effective route to commercial property AVM:
  – Start with rent (Big Data available) – Focus of our project
  – CRE value can then be estimated by combining with additional approaches

» Machine learning shows promising improvements over traditional methods
  – K-nearest neighbors algorithm automates comps selection
  – Gradient Boosting algorithm minimizes office rent prediction error to ~10%

» Automated rent prediction has tremendous value across multiple business fronts
CREDIT RATINGS ISSUED BY MOODY'S INVESTORS SERVICE, INC. AND ITS RATINGS AFFILIATES ("MIS") ARE MOODY'S CURRENT OPINIONS OF THE RELATIVE FUTURE CREDIT RISK OF ENTITIES, COMMITMENTS, OR DEBT OR DEBT-LIKE SECURITIES, AND MOODY'S PUBLICATIONS MAY INCLUDE MOODY'S CURRENT OPINIONS OF THE RELATIVE FUTURE CREDIT RISK OF ENTITIES, COMMITMENTS, OR DEBT OR DEBT-LIKE SECURITIES. MOODY'S DEFINES CREDIT RISK AS THE RISK THAT AN ENTITY MAY NOT MEET ITS CONTRACTUAL FINANCIAL OBLIGATIONS AS THEY COME DUE AND ANY ESTIMATED FINANCIAL LOSS IN THE EVENT OF DEFAULT. CREDIT RATINGS DO NOT ADDRESS ANY OTHER RISK, INCLUDING BUT NOT LIMITED TO: LIQUIDITY RISK, MARKET VALUE RISK, OR PRICE VOLATILITY. CREDIT RATINGS AND MOODY'S OPINIONS INCLUDED IN MOODY'S PUBLICATIONS ARE NOT STATEMENTS OF CURRENT OR HISTORICAL FACT. MOODY'S PUBLICATIONS MAY ALSO INCLUDE QUANTITATIVE MODEL-BASED ESTIMATES OF CREDIT RISK AND RELATED OPINIONS OR COMMENTARY PUBLISHED BY MOODY'S ANALYTICS, INC. CREDIT RATINGS AND MOODY'S PUBLICATIONS DO NOT CONSTITUTE OR PROVIDE INVESTMENT OR FINANCIAL ADVICE, AND CREDIT RATINGS AND MOODY'S PUBLICATIONS ARE NOT AND DO NOT PROVIDE RECOMMENDATIONS TO PURCHASE, SELL, OR HOLD PARTICULAR SECURITIES. NEITHER CREDIT RATINGS NOR MOODY'S PUBLICATIONS COMMENT ON THE SUITABILITY OF AN INVESTMENT FOR ANY PARTICULAR INVESTOR. MOODY'S ISSUES ITS CREDIT RATINGS AND PUBLICATIONS WITH THE EXPECTATION AND UNDERSTANDING THAT EACH INVESTOR WILL, WITH DUE CARE, MAKE ITS OWN STUDY AND EVALUATION OF EACH SECURITY THAT IS UNDER CONSIDERATION FOR PURCHASE, HOLDING, OR SALE.

MOODY'S CREDIT RATINGS AND MOODY'S PUBLICATIONS ARE NOT INTENDED FOR USE BY RETAIL INVESTORS AND IT WOULD BE REDUNDANT AND INAPPROPRIATE FOR RETAIL INVESTORS TO USE MOODY'S CREDIT RATINGS OR MOODY'S PUBLICATIONS WHEN MAKING AN INVESTMENT DECISION. IF IN DOUBT YOU SHOULD CONTACT YOUR FINANCIAL OR OTHER PROFESSIONAL ADVISER.

ALL INFORMATION CONTAINED HEREIN IS PROTECTED BY LAW, INCLUDING BUT NOT LIMITED TO, COPYRIGHT LAW, AND NONE OF SUCH INFORMATION MAY BE COPIED OR OTHERWISE REPRODUCED, REPACKAGED, FURTHER TRANSMITTED, TRANSFERRED, DISSEMINATED, REDISTRIBUTED OR RESOLD, OR STORED FOR SUBSEQUENT USE FOR ANY SUCH PURPOSE, IN WHOLE OR IN PART, IN ANY FORM OR MANNER OR BY ANY MEANS WHATSOEVER, BY ANY PERSON WITHOUT MOODY'S PRIOR WRITTEN CONSENT.

CREDIT RATINGS AND MOODY'S PUBLICATIONS ARE NOT INTENDED FOR USE BY ANY PERSON AS A BENCHMARK AS THAT TERM IS DEFINED FOR REGULATORY PURPOSES AND MUST NOT BE USED IN ANY WAY THAT COULD RESULT IN THEM BEING CONSIDERED A BENCHMARK.

All information contained herein is obtained by MOODY'S from sources believed by it to be accurate and reliable. Because of the possibility of human or mechanical error as well as other factors, however, all information contained herein is provided "AS IS" without warranty of any kind. MOODY'S adopts all necessary measures so that the information it uses in assigning a credit rating is of sufficient quality and from sources MOODY'S considers to be reliable including, when appropriate, independent third-party sources. However, MOODY'S is not an auditor and cannot in every instance independently verify or validate information received in the rating process or in preparing the Moody's publications.

To the extent permitted by law, MOODY'S and its directors, officers, employees, agents, representatives, licensors and suppliers disclaim liability to any person or entity for any indirect, special, consequential, or incidental losses or damages whatsoever arising from or in connection with the information contained herein or the use of or inability to use any such information, even if MOODY'S or any of its directors, officers, employees, agents, representatives, licensors or suppliers is advised in advance of the possibility of such losses or damages, including but not limited to: (a) any loss of present or prospective profits or (b) any loss or damage arising where the relevant financial instrument is not the subject of a particular credit rating assigned by MOODY'S.

To the extent permitted by law, MOODY'S and its directors, officers, employees, agents, representatives, licensors and suppliers disclaim liability for any direct or compensatory losses or damages caused to any person or entity, including but not limited to by any negligence, (but excluding fraud, willful misconduct or any other type of liability that, for the avoidance of doubt, by law cannot be excluded) on the part of, or any contingency within or beyond the control of, MOODY'S or any of its directors, officers, employees, agents, representatives, licensors or suppliers, arising from or in connection with the information contained herein or the use of or inability to use any such information.

NO WARRANTY, EXPRESS OR IMPLIED, AS TO THE ACCURACY, TIMENESS, COMPLETENESS, MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE OF ANY SUCH RATING OR OTHER OPINION OR INFORMATION IS GIVEN OR MADE BY MOODY'S IN ANY FORM OR MANNER WHATSOEVER.

Moody's Investors Service, Inc., a wholly-owned credit rating agency subsidiary of Moody's Corporation ("MCO"), hereby discloses that most issuers of debt securities (including corporate and municipal bonds, debentures, notes and commercial paper) and preferred stock rated by Moody's Investors Service, Inc. have, prior to assignment of any rating, agreed to pay to Moody's Investors Service, Inc. for appraisal and rating services rendered by it fees ranging from $1,500 to approximately $2,500,000. MCO and MIS also maintain policies and procedures to address the independence of MIS's ratings and rating processes. Information regarding certain affiliations that may exist between directors of MCO and rated entities, and between entities who hold ratings from MIS and have also publicly reported to the SEC an ownership interest in MCO of more than 5%, is posted annually at www.moodys.com under the heading "Investor Relations — Corporate Governance — Director and Shareholder Affiliation Policy."

Additional terms for Australia only: Any publication into Australia of this document is pursuant to the Australian Financial Services License of MOODY's affiliate, Moody's Investors Service Pty Limited ABN 61 003 399 657AFSL 36969 and/or Moody's Analytics Australia Pty Ltd ABN 94 105 136 972 AFSL 385399 (as applicable). This document is intended to be provided only to "wholesale clients" within the meaning of section 761G of the Corporations Act 2001. MOODY's credit rating is an opinion as to the creditworthiness of a debt obligation of the issuer, on the equity of the issuer or on any financial institution of any sort that is available to retail investors. It would be reckless and inappropriate for retail investors to use MOODY's credit ratings or publications when making an investment decision. If in doubt you should contact your financial or other professional adviser.

Additional terms for Japan only: Moody's Japan K.K. ("MJKK") is a wholly-owned credit rating agency subsidiary of Moody's Group Japan K.G., which is wholly-owned by Moody's Overseas Holdings Inc., a wholly-owned subsidiary of MCO. Moody's Japan K.K. ("MSFJ") is a wholly-owned credit rating agency subsidiary of MJKK. MSFJ is not a Nationally Recognized Statistical Rating Organization ("NRSRO"). Therefore, credit ratings assigned by MSFJ are Non-NRSRO Credit Ratings. Non-NRSRO Credit Ratings are assigned by an entity that is not a NRSRO and, consequently, the rated obligation will not qualify for certain types of treatment under U.S. laws. MJKK and MSFJ are credit rating agencies registered with the Japanese Financial Services Agency and their registration numbers are FSA Commissioner (Ratings) No. 2 and 3 respectively. MJKK or MSFJ (as applicable) hereby disclose that most issuers of debt securities (including corporate and municipal bonds, debentures, notes and commercial paper) and preferred stock rated by MJKK or MSFJ (as applicable) have, prior to assignment of any rating, agreed to pay to MJKK or MSFJ (as applicable) for appraisal and rating services rendered by it fees ranging from JPY200,000 to approximately JPY350,000,000. MJKK and MSFJ also maintain policies and procedures to address Japanese regulatory requirements.