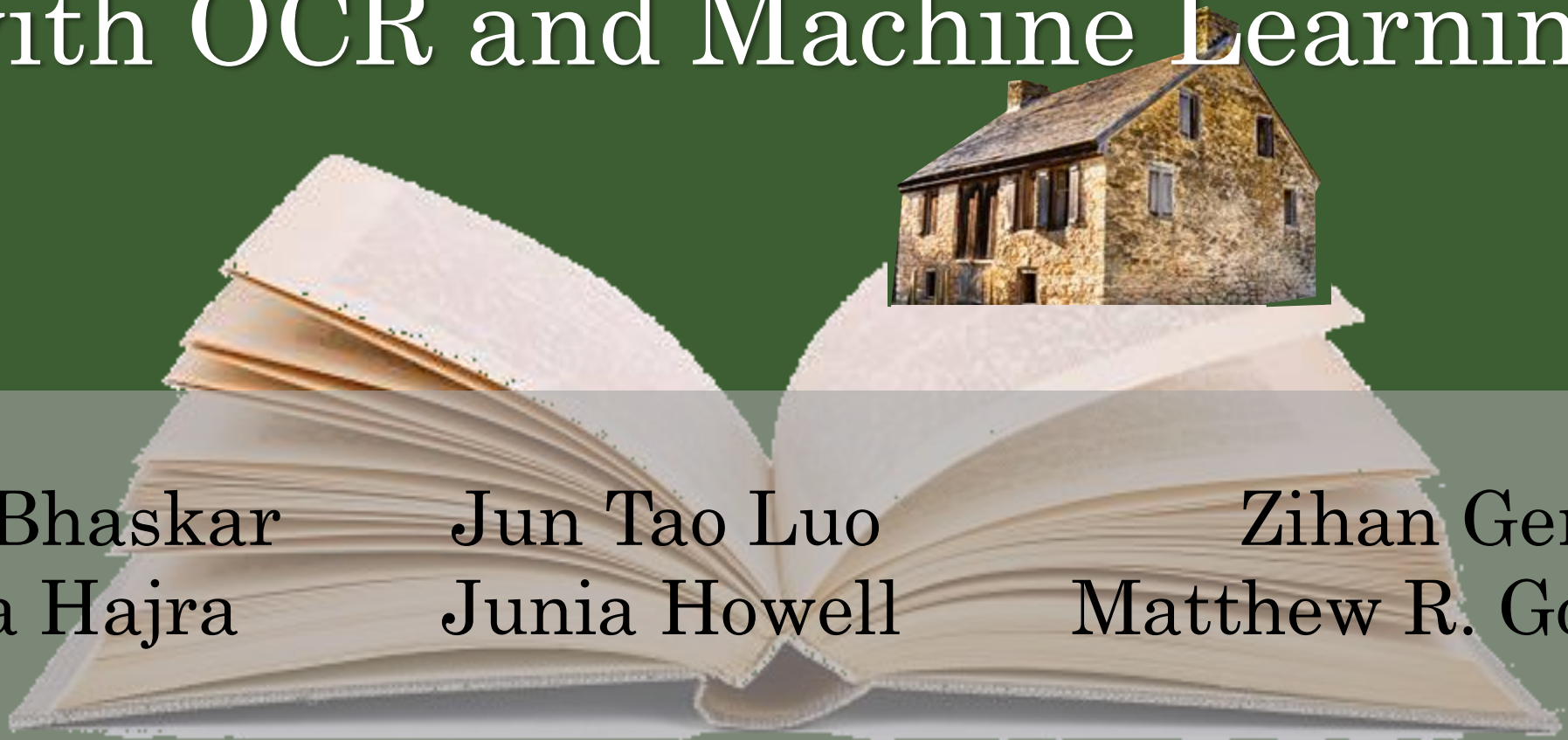
Predicting the Past:

Estimating Historical Appraisals with OCR and Machine Learning



Mihir Bhaskar
Asmita Hajra
Jun Tao Luo
Junia Howell
Zihan Geng
Matthew R. Gormley


$900,000
$290,000
$90,000

Appraised:

The Persistent Evaluation of White Neighborh
as More Valuable Than Communities of Co

JUNIA HOWELL
ELIZABETH KORVER-GLENN

NOVEMBER 2022

Social Problems, 2020, 0, 1–21
doi: 10.1093/socpro/spaa033
Article

OXFORD

The Increasing Effect of Neighborhood Racial Composition on Housing Values, 1980–2015

Junia Howell[1] and Elizabeth Korver-Glenn[2]

[1]University of Pittsburgh, [2]University of New Mexi

ABSTRACT

Beginning in the 1930s, neighborhood racial composition
factor in the evaluation of U.S. home values. This deliberate p
1960s and 1970s, but the correlation between neighborhood r
values persists. Using Census Bureau data from 1980 to 2015,
the changing relationship between neighborhood racial com
as well as the mechanisms that drive it. Contrary to what is c
racial composition was a stronger determinant of appraised
1980. Results suggest this is primarily due to conte
Specifically, the use of the sales comparison approach h
appraisals to influence contemporary values and appraise
neighborhoods to drive appraisal methods. These findings
sistent racial inequality is driven in part by perpetual deva
they suggest further regulation is required to foster equity

KEYWORDS: racial inequality; appraisals; housing
redlining.

Neighborhoods, Race, and the Twenty-first-century Housing Appraisal Industry

Junia Howell[1] and Elizabeth Korver-Glenn[2]

Sociology of Race and Ethnicity
2018, Vol. 4(4) 473–490

DOI: 10.1177/2332649218755178
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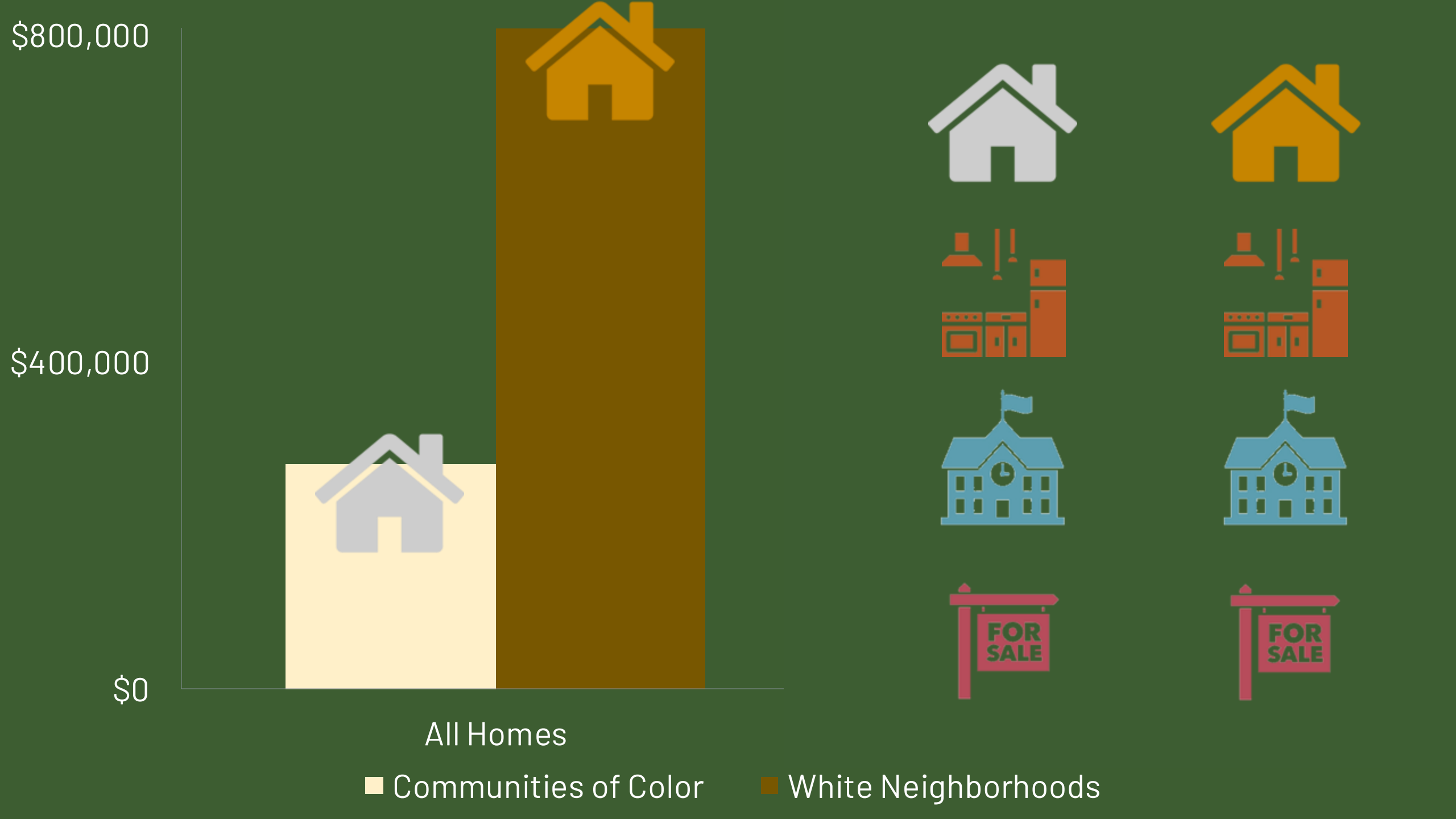
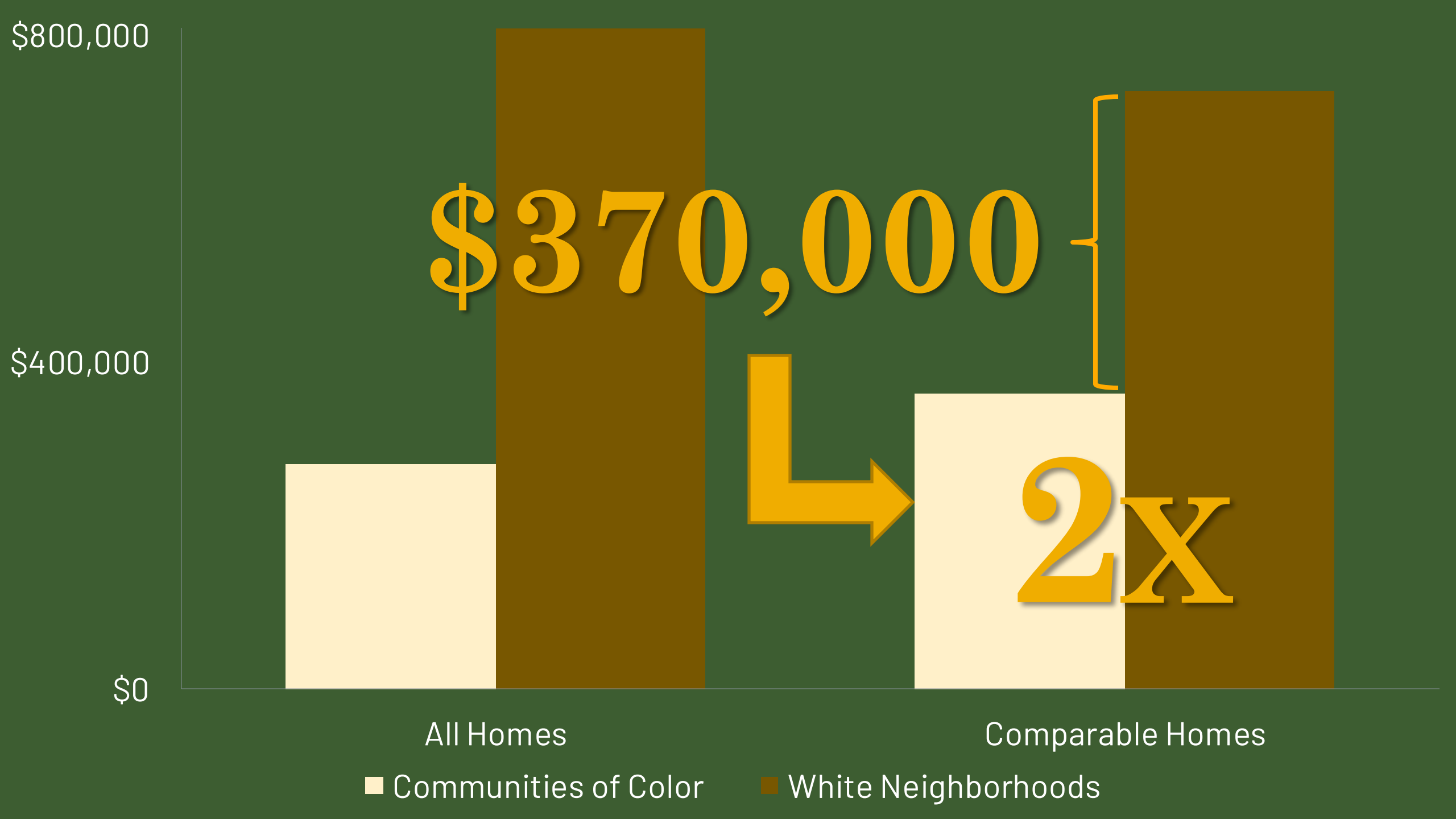
Abstract

The history of the U.S. housing market is bound up in systemic, explicit racism. However, little research has investigated whether racial inequality also persists in the contemporary appraisal industry and, if present, how it happens. The present article addresses this gap by centering the appraisal industry as a key housing market player in the reproduction of racial inequality. Using a census of all single-family tax-appraised homes in Harris County (Houston), Texas, the authors examine the influence of neighborhood racial composition on home values independent of home characteristics and quality; neighborhood housing stock, socioeconomic status, and amenities; and consumer housing demand. Noting that substantial neighborhood racial inequality in home values persists even when these variables are accounted for, the authors then use ethnographic and interview data to investigate the appraisal processes that enable this inequality to continue. The findings suggest that variation in appraisal methods coupled with appraisers' racialized perceptions of neighborhoods perpetuates neighborhood racial disparities in home value. The authors conclude with suggestions for future research and policy interventions aimed at standardizing the appraisal process.


$800,000
$400,000
$0
All Homes
Communities of Color
White Neighborhoods


$800,000
$400,000
$0
All Homes
Communities of Color
White Neighborhoods
FOR SALE
FOR SALE


$800,000
$400,000
$0
All Homes
Comparable Homes
Communities of Color
White Neighborhoods


$800,000
$400,000
$0
$370,000
2x
All Homes
Comparable Homes
Communities of Color
White Neighborhoods

Appraised:

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JUNIA HOWELL
ELIZABETH KORVER-GLENN

NOVEMBER 2022

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OXFORD

The Increasing Effect of Neighborhood Racial Composition on Housing Values, 1980–2015

Junia Howell[1] and Elizabeth Korver-Glenn[2]

[1]University of Pittsburgh, [2]University of New Mexico

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drive appraisal methods. These findings provide strong evidence that per-
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Neighborhoods, Housing, and Racial Segregation

Neighborhoods, Race, and the Twenty-first-century Housing Appraisal Industry

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1920

$1000

$1500

$50

1920

One Story Single Family Homes

square feet	1-bed	2-bed	3-bed	4-bed	5-bed	6-bed
under 100	$1500	$1600	$1700	$1800	$1900	$2000
100-200	$2000	$2100	$2200	$2300	$2400	$2500
200-300	$2500	$2600	$2700	$2800	$2900	$3000
300-400	$3000	$3100	$3200	$3300	$3400	$3500
400-500	$3500	$3600	$3700	$3800	$3900	$4000
500-600	$4000	$4100	$4200	$4300	$4400	$4500
600-700	$4500	$4600	$4700	$4800	$4900	$5000
700-800	$5000	$5100	$5200	$5300	$5400	$5500
800-900	$5500	$5600	$5700	$5800	$5900	$6000
900-1000	$6000	$6100	$6200	$6300	$6400	$6500

1920

1920

1929

1920

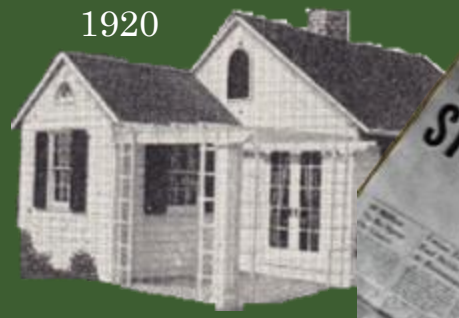
1929

1932

1920

1929

1934

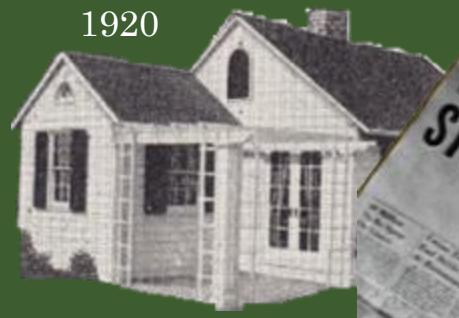


1932

1920

1929

1934



1920

1929

UNDERWRITING MANUAL

UNDERWRITING AND VALUATION PROCEDURE
UNDER TITLE II
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With revisions to April 1, 1936

WASHINGTON, D. C.

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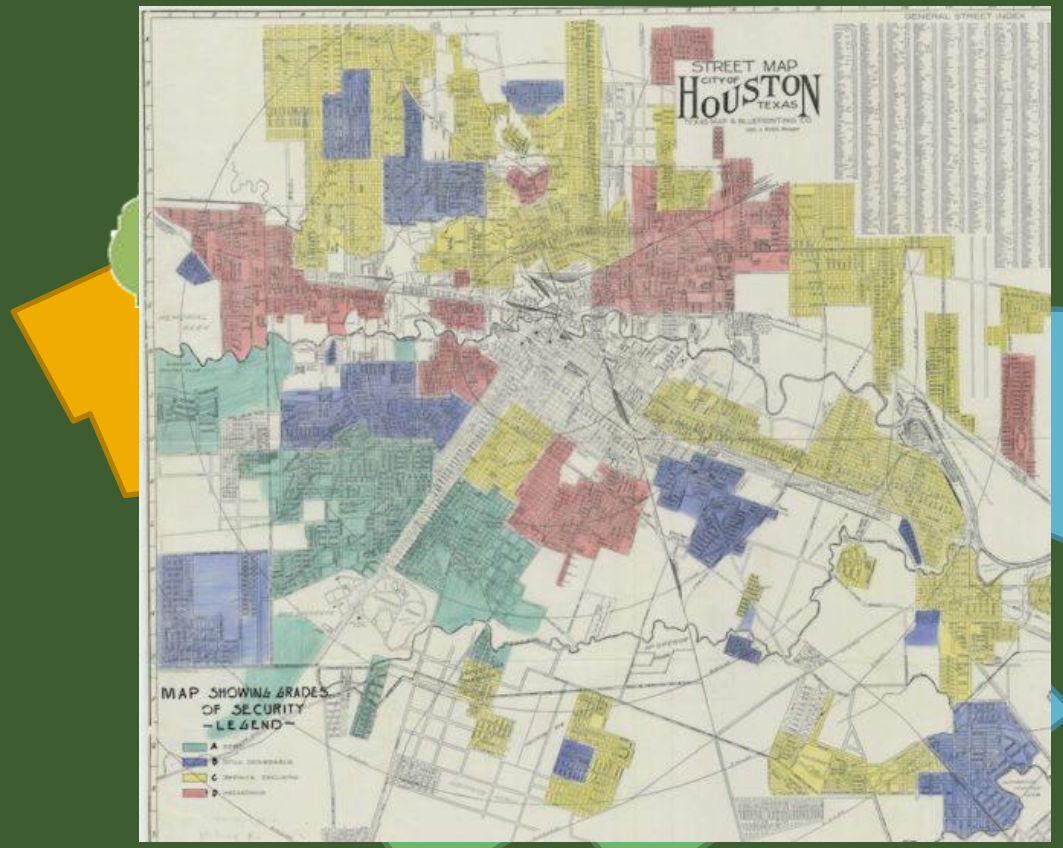
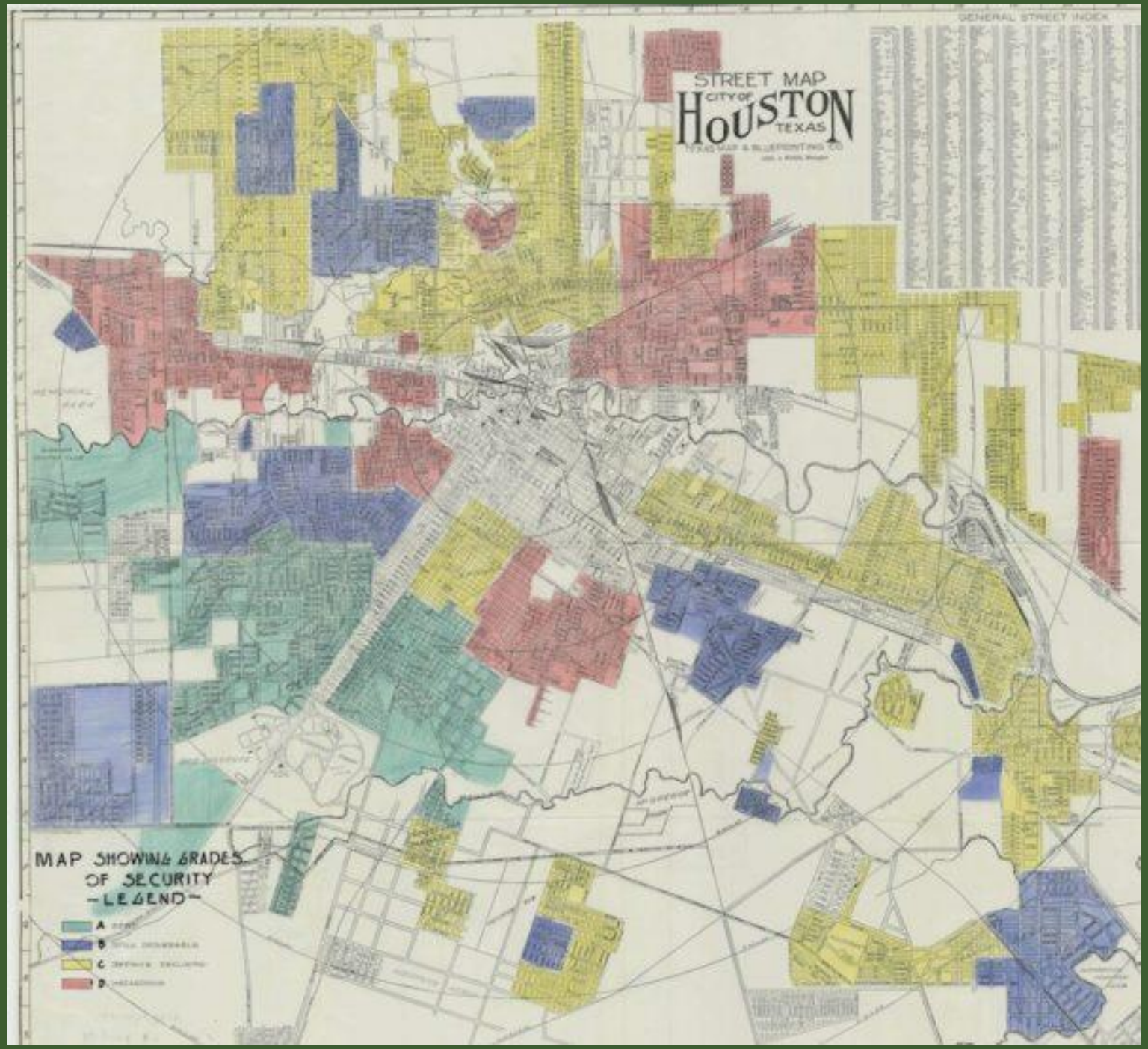



GENERAL STREET INDEX
STREET MAP
CITY OF
HOUSTON
TEXAS
MAP SHOWING GRADES
OF SECURITY
-LEGEND-

1932

EQUAL HOUSING OPPORTUNITY

AMERICAN INSTITUTE ·OF· REAL ESTATE APPRAISERS

1976

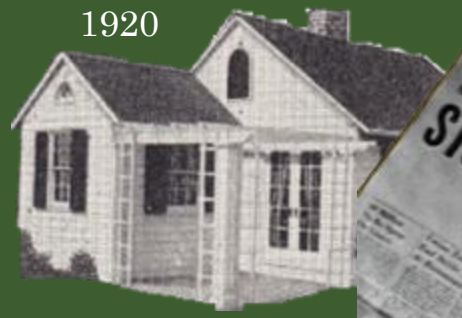
1920

1929

1934

1968

1977



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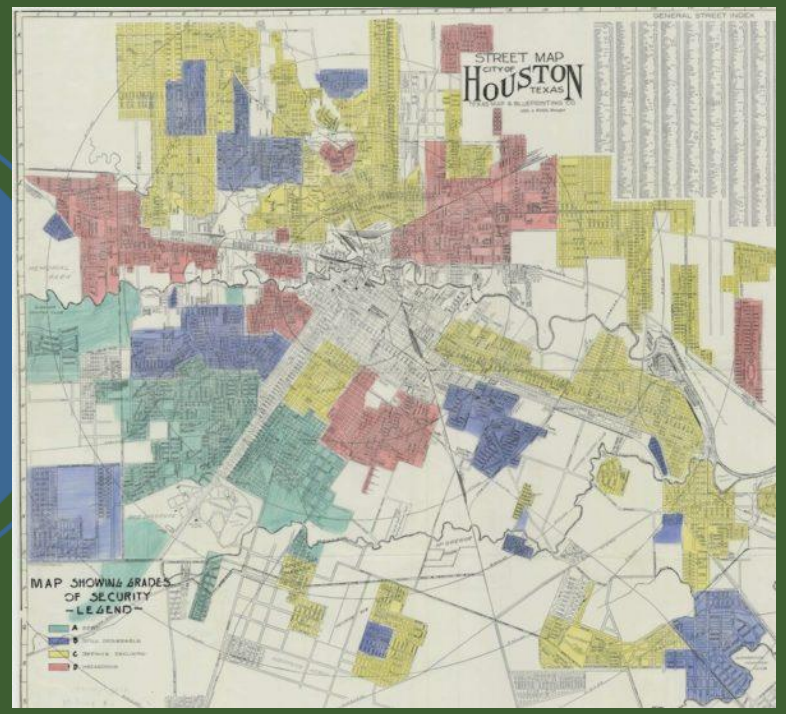


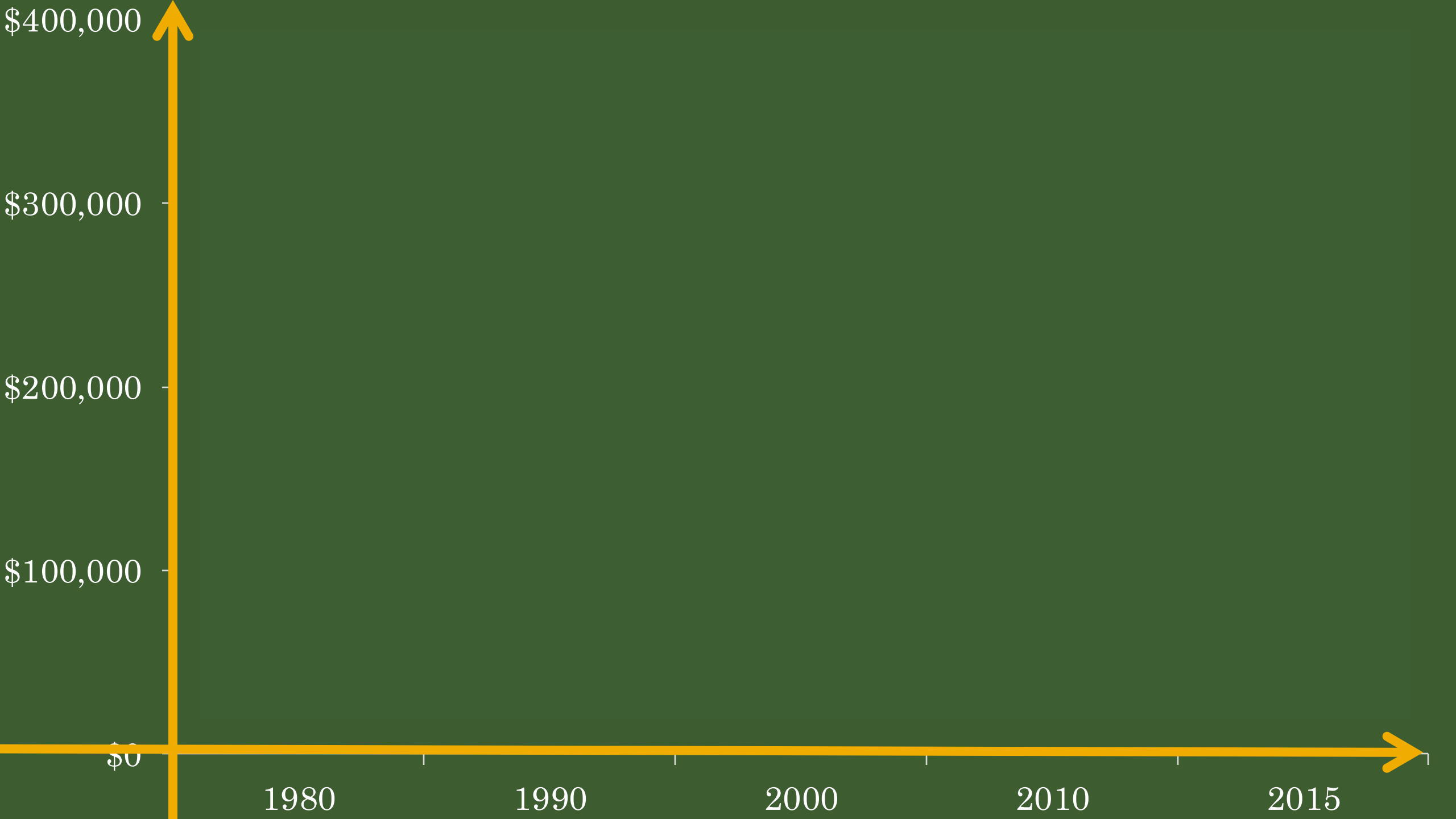
EQUAL HOUSING OPPORTUNITY

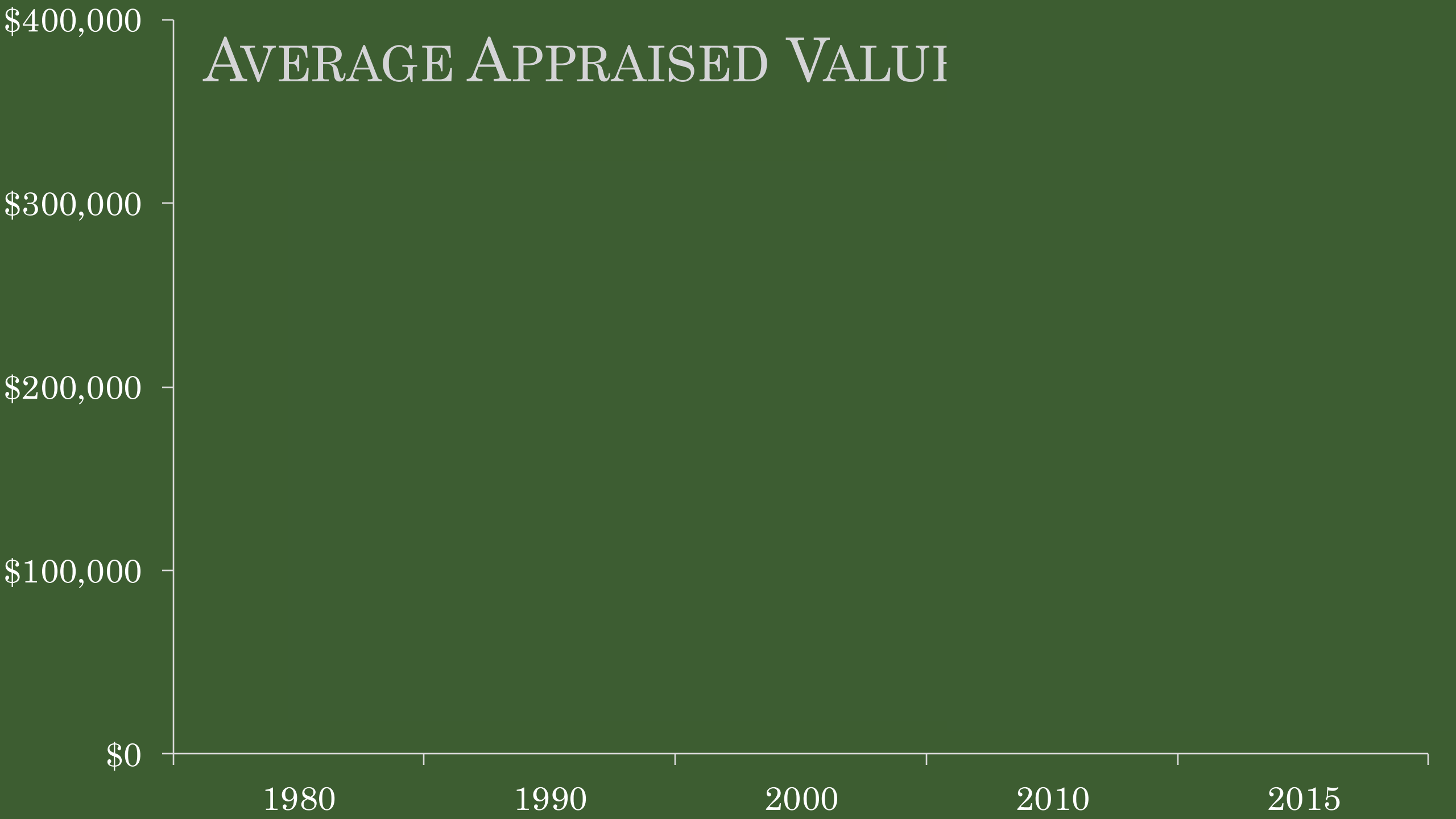
AMERICAN INSTITUTE -OF- REAL ESTATE APPRAISERS

1976

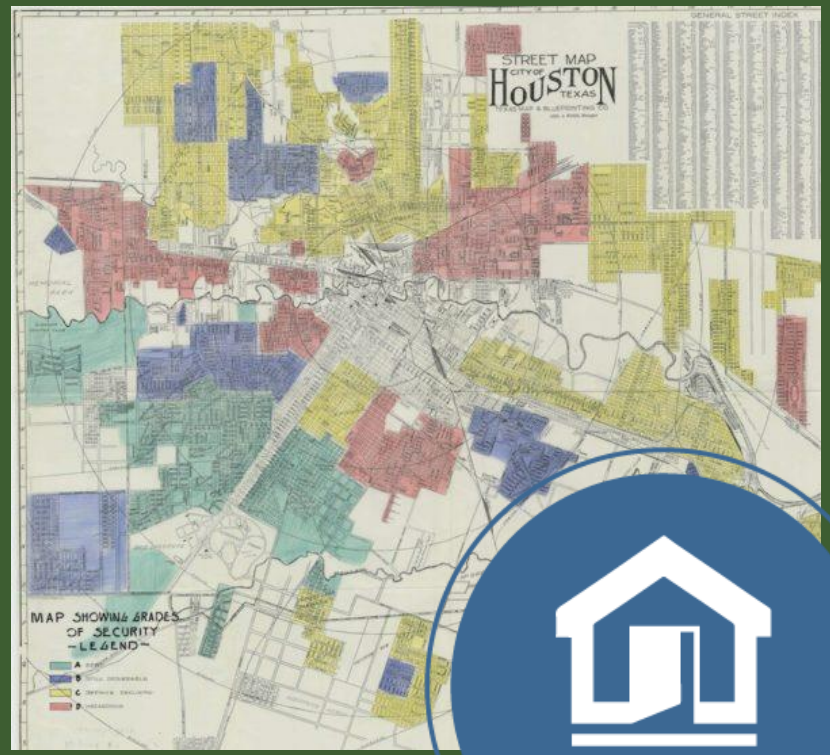
1968

1977


$400,000
$300,000
$200,000
$100,000
$0
1980
1990
2000
2010
2015


Average Appraised Valui
$400,000
$300,000
$200,000
$100,000
$0
1980
1990
2000
2010
2015

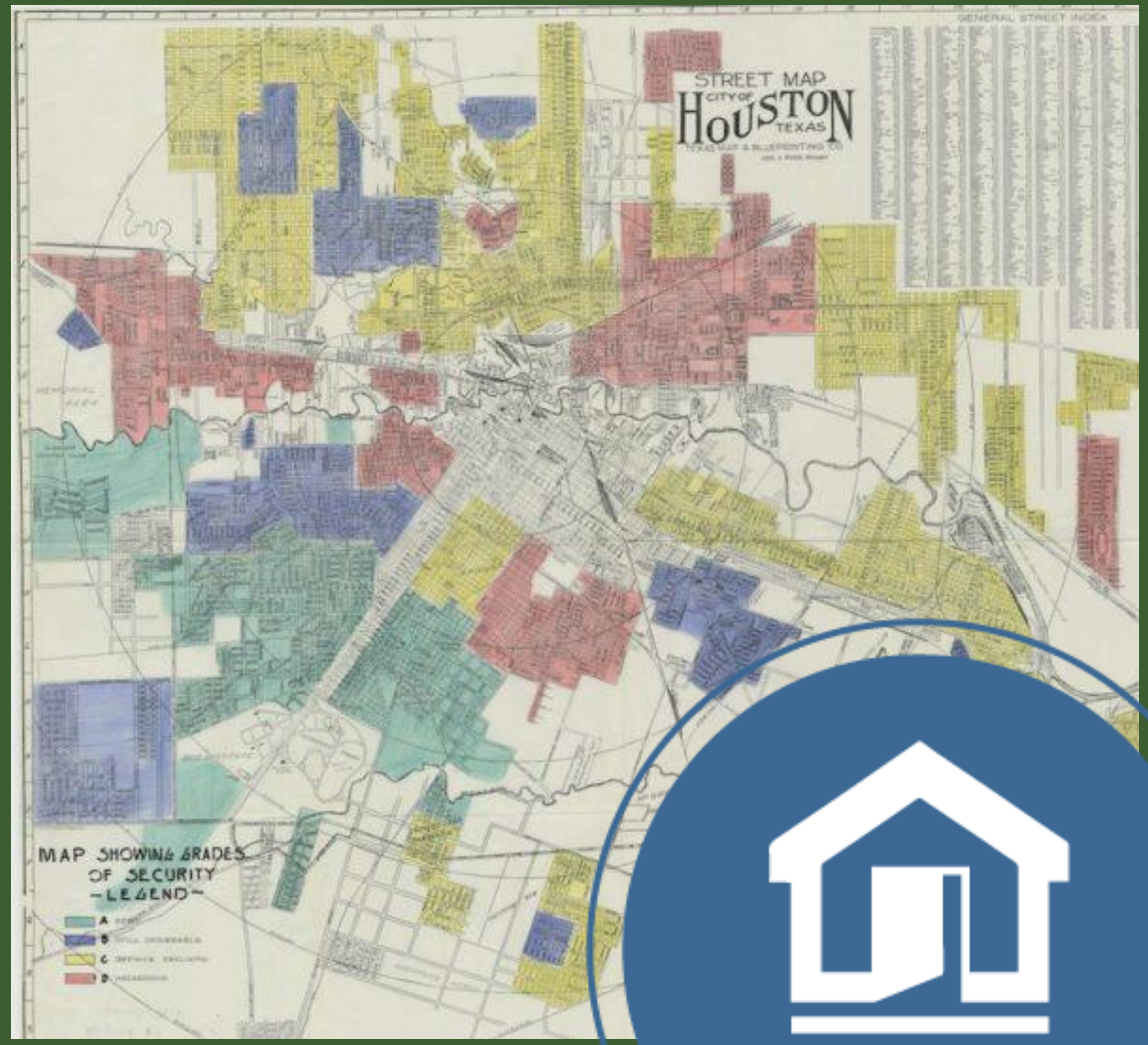
Average Appraised Value



$400,000
$300,000
$200,000
$100,000
$0

1980
1990
2000
2010
2015

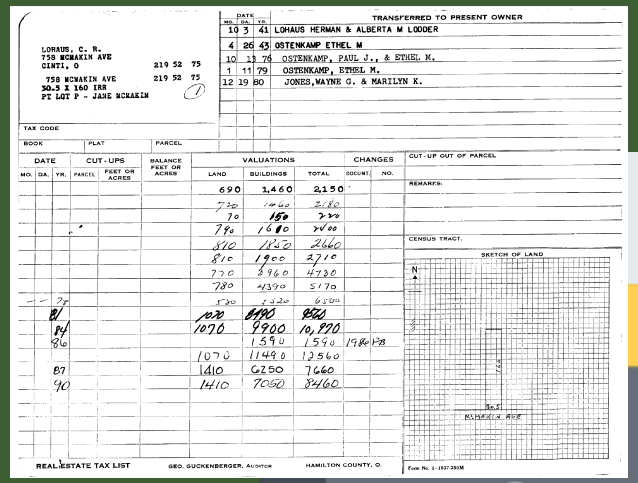
White Neighborhoods
Communities of Color


STREET MAP
CITY OF
HOUSTON
TEXAS
MAP SHOWING GRADES
OF SECURITY
-LEGEND-

good news

good news

good news



LOHAUS, C. R.
758 MCMAKIN AVE
CINTI, O

758 MCMAKIN AVE 219 52 75
30.5 X 160 IRR
PT LOT P - JANE MCMAKIN

TRANSFERRED TO PRESENT OWNER

DATE MO.	DA.	YR.	
10	3	41	LOHAUS HERMAN & ALBERTA M LOODER
4	26	43	OSTENKAMP ETHEL M
10	13	76	OSTENKAMP, PAUL J., & ETHEL M.
1	11	79	OSTENKAMP, ETHEL M.
12	19	80	JONES, WAYNE G. & MARILYN K.

TAX CODE
BOOK PLAT PARCEL

DATE MO.	DA.	YR.	CUT-UPS PARCEL	FEET OR ACRES	BALANCE FEET OR ACRES	VALUATIONS LAND	BUILDINGS	TOTAL	CHANGES DOCUMENT NO.
						690	1460	2150	
						730	1460	2190	
						70	150	220	
						790	1610	2400	
						810	1850	2660	
						810	1900	2710	
						770	3960	4730	
						780	4390	5170	
						530	1120	6500	
						1070	8830	9900	
						1070	9900	10,970	
							1590	1590	1786 78
						1070	11490	12560	
						1410	6250	7660	
						1410	7050	8460	

CUT-UP OUT OF PARCEL
REMARKS:
CENSUS TRACT.
SKETCH OF LAND

REAL ESTATE TAX LIST GEO. GUCKENBERGER, AUDITOR HAMILTON COUNTY, O.

LOHAUS, C. R.
758 MCMAKIN AVE
CINTI, O

219 52 75

758 MCMAKIN AVE
30.5 X 160 IRR
PT LOT P - JANE MCMAKIN

219 52 75

(1)

TAX CODE

BOOK | PLAT | PARCEL

DATE MO.	DA.	YR.	TRANSFERRED TO PRESENT OWNER
10	3	41	LOHAUS HERMAN & ALBERTA M LODDER
4	26	43	OSTENKAMP ETHEL M
10	13	76	OSTENKAMP, PAUL J., & ETHEL M.
1	11	79	OSTENKAMP, ETHEL M.
12	19	80	JONES, WAYNE G. & MARILYN K.

1933

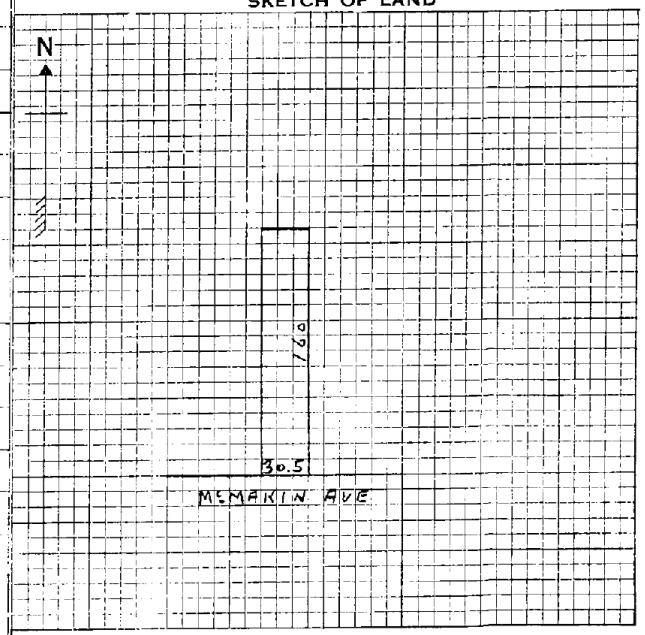
DATE MO.	DA.	YR.	CUT-UPS PARCEL	FEET OR ACRE	BALANCE FEET OR ACRE	VALUATIONS LAND	BUILDINGS	TOTAL	CHANGES DOCUMT.	NO.
						690	1,460	2,150		
						720		2180		
						70	150	220		
						790	1610	2400		
						810	1850	2660		
						810	1900	2710		
						770	2960	4730		
						780	4390	5170		
		78				520	5520	6500		
	81					1070	8490	9560		
	84					1070	9900	10,970		
	86						1590	1590	1986	PB
						1070	11490	12560		
	87					1410	6250	7660		
	90					1410	7050	8460		

CUT-UP OUT OF PARCEL

REMARKS:

CENSUS TRACT.

SKETCH OF LAND



REAL ESTATE TAX LIST | GEO. GUCKENBERGER, AUDITOR | HAMILTON COUNTY, O.

Form No. 1-1937-250M

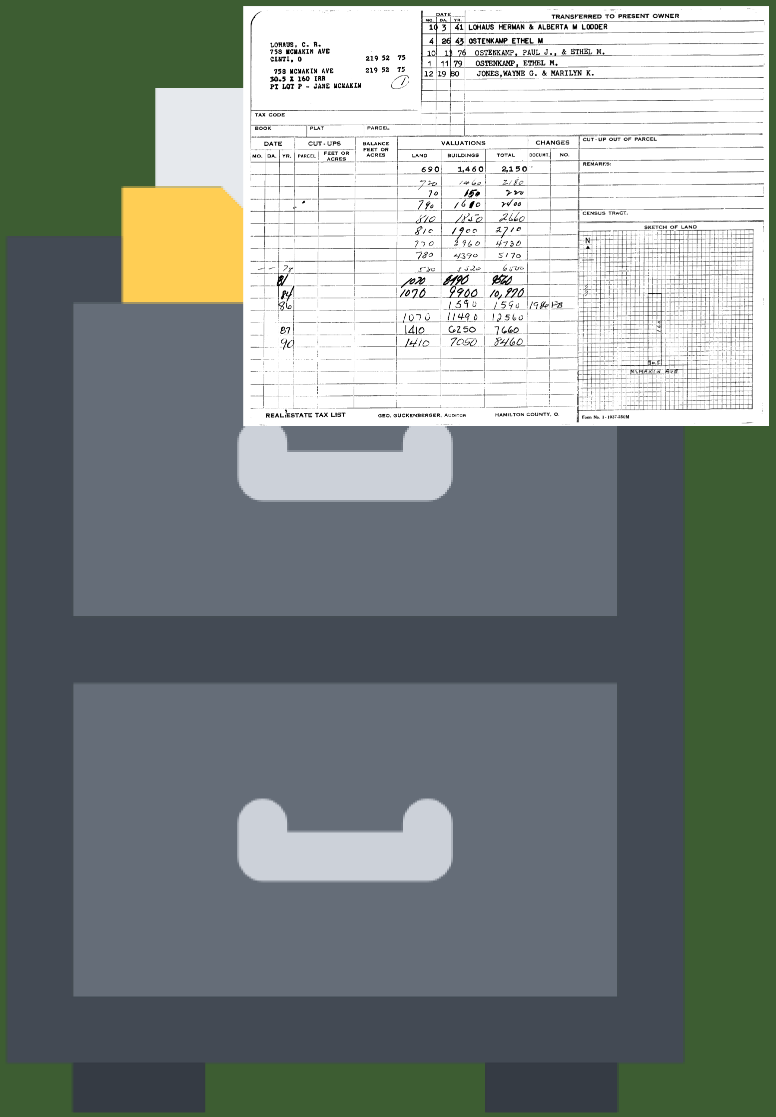
good news

good news

good news

bad news

bad news


LOHAUS, C. R.
758 MCMAKIN AVE
CINTI, O
219 52 75
758 MCMAKIN AVE
219 52 75
30.5 X 160 IRR
PT LOT P - JANE MCMAKIN
DATE
MO. DA. YR.
TRANSFERRED TO PRESENT OWNER
10 3 41 LOHAUS HERMAN & ALBERTA M LODDER
4 26 43 OSTENKAMP ETHEL M
10 13 76 OSTENKAMP, PAUL J., & ETHEL M.
1 11 79 OSTENKAMP, ETHEL M.
12 19 80 JONES,WAYNE G. & MARILYN K.
TAX CODE
BOOK
PLAT
PARCEL
DATE
CUT-UPS
PARCEL
FEET OR ACRES
BALANCE FEET OR ACRES
VALUATIONS
LAND
BUILDINGS
TOTAL
CHANGES
DOCUMT.
NO.
690 1,460 2,150
CUT-UP OUT OF PARCEL
REMARKS:
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SKETCH OF LAND
REAL ESTATE TAX LIST
GEO. GUCKENBERGER, Auditor
HAMILTON COUNTY, O.
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bad news

LOHAUS, C. R.
758 MCMAKIN AVE
CINTI, O 219 52 75

758 MCMAKIN AVE 219 52 75
30.5 X 160 IRR
PT LOT P - JANE MCMAKIN
(1)

TAX CODE

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		86					1590	1590	1986	PB
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		87				1410	6250	7660		
		90				1410	7050	8460		

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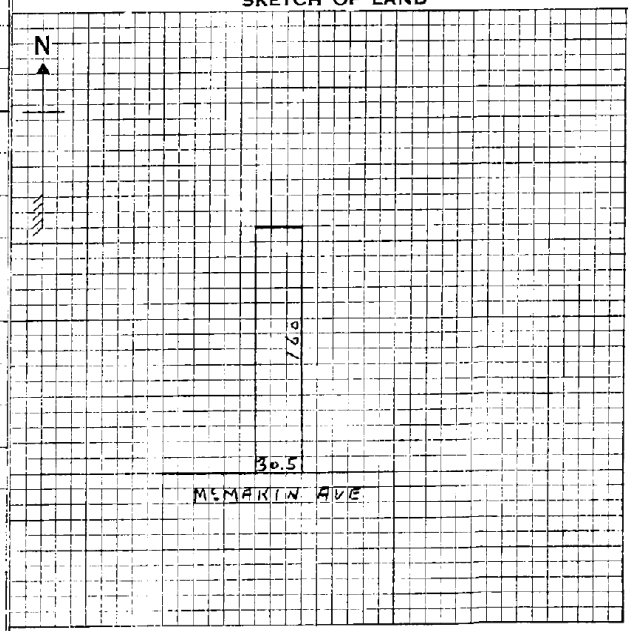

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Form No. 1-1937-250M

LOHAUS, C. R.
758 MCMAKIN AVE
CINTI, O

219 52 75

758 MCMAKIN
30 E

219 52 75

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12	19	80	JONES, WAYNE G. & MARILYN K.

...TIONS ...NGS	TOTAL	CHA... DOCUM...
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...	2180	
...	2720	
...	2400	
...	2660	
...	2710	
...	4730	
...	5170	
...	6500	
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...00	10,970	
...90	1590	1986 H
1490	12560	
6250	7660	
7050	8460	

MCMARTIN

REAL ESTATE TAX LIST GEO. GUCKENBERGER, AUDITOR HAMILTON COUNTY, O.

Form No. 1-1937-250M

tabulation

scanning

Building Dataset

Predicting Values

Building Dataset

LOHAUS, C. R.
758 MCMAKIN AVE
CINTI, O

758 MCMAKIN AVE
30.5 X 160 IRR
PT LOT P - JANE MCMAKIN

219 52 75
219 52 75

(1)

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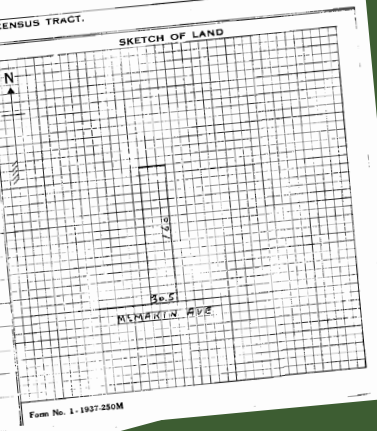
		84					1590	1590	1986	PB
		86				1070	11490	12560		
		87				1410	6250	7660		
		90				1410	7050	8460		

CUT-UP OUT OF PARCEL

REMARKS:

CENSUS TRACT.

SKETCH OF LAND



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Form No. 1-1937-250M

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CINTI, O 219 52 75

758 MCMAKIN AVE 219 52 75
30.5 X 160 IRR
PT LOT P - JANE MCMAKIN (1)

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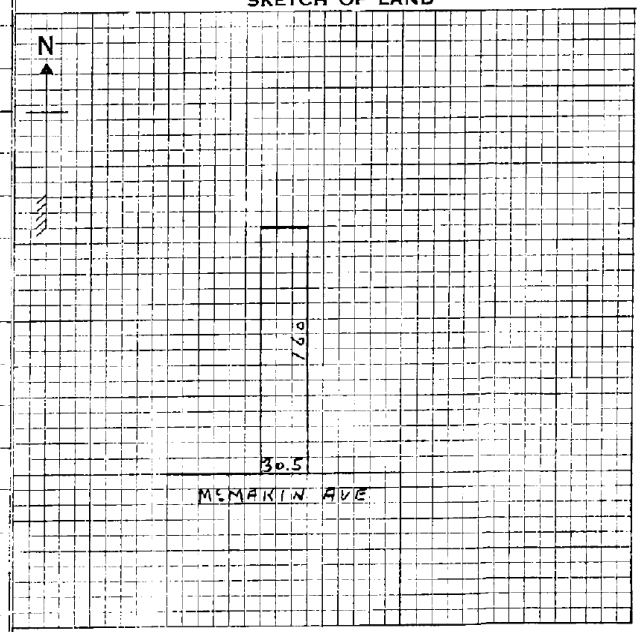
		84				1070	9900	10,970		
		86					1590	1590	1986	PB
						1070	11490	12560		
		87				1410	6250	7660		
		90				1410	7050	8460		

CUT-UP OUT OF PARCEL

REMARKS:

CENSUS TRACT.

SKETCH OF LAND



REAL ESTATE TAX LIST GEO. GUCKENBERGER, AUDITOR HAMILTON COUNTY, O.

Form No. 1-1937-250M

LOHAUS, C. R.
758 MCMAKIN AVE
CINTI, O

219 52 75

758 MCMAKIN AVE
30.5 X 160 IRR
PT LOT P - JANE MCMAKIN

219 52 75

(1)

TAX CODE

BOOK | PLAT | PARCEL

DATE MO.	DA.	YR.	TRANSFERRED TO PRESENT OWNER
10	3	41	LOHAUS HERMAN & ALBERTA M LODDER
4	26	43	OSTENKAMP ETHEL M
10	13	76	OSTENKAMP, PAUL J., & ETHEL M.
1	11	79	OSTENKAMP, ETHEL M.
12	19	80	JONES, WAYNE G. & MARILYN K.

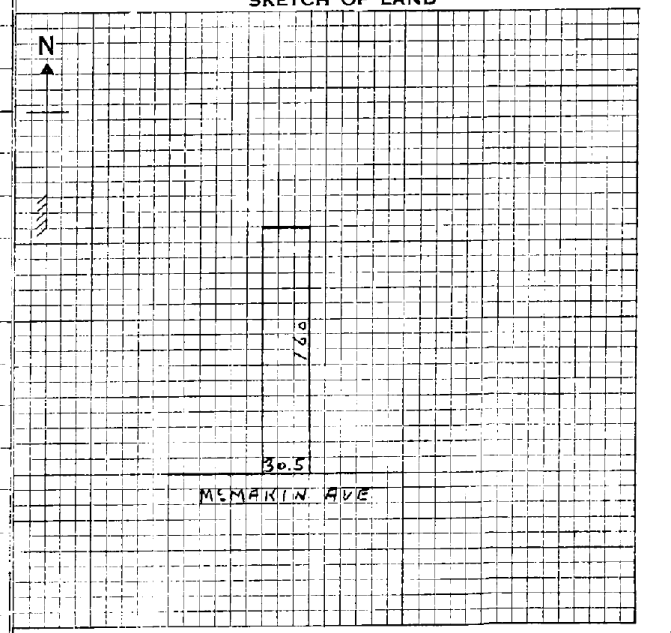
DATE MO.	DA.	YR.	CUT-UPS PARCEL	FEET OR ACRES	BALANCE FEET OR ACRES	VALUATIONS LAND	BUILDINGS	TOTAL	CHANGES DOCUMT.	NO.
						690	1,460	2,150		
						720		2180		
						70	150	220		
						790	1610	2400		
						810	1850	2660		
						810	1900	2710		
						770	3960	4730		
						780	4390	5170		
—	—	78				580	5520	6500		
		81				1070	8490	9560		
		84				1070	9900	10,970		
		86					1590	1590	1986	PB
						1070	11490	12560		
		87				1410	6250	7660		
		90				1410	7050	8460		

CUT-UP OUT OF PARCEL

REMARKS:

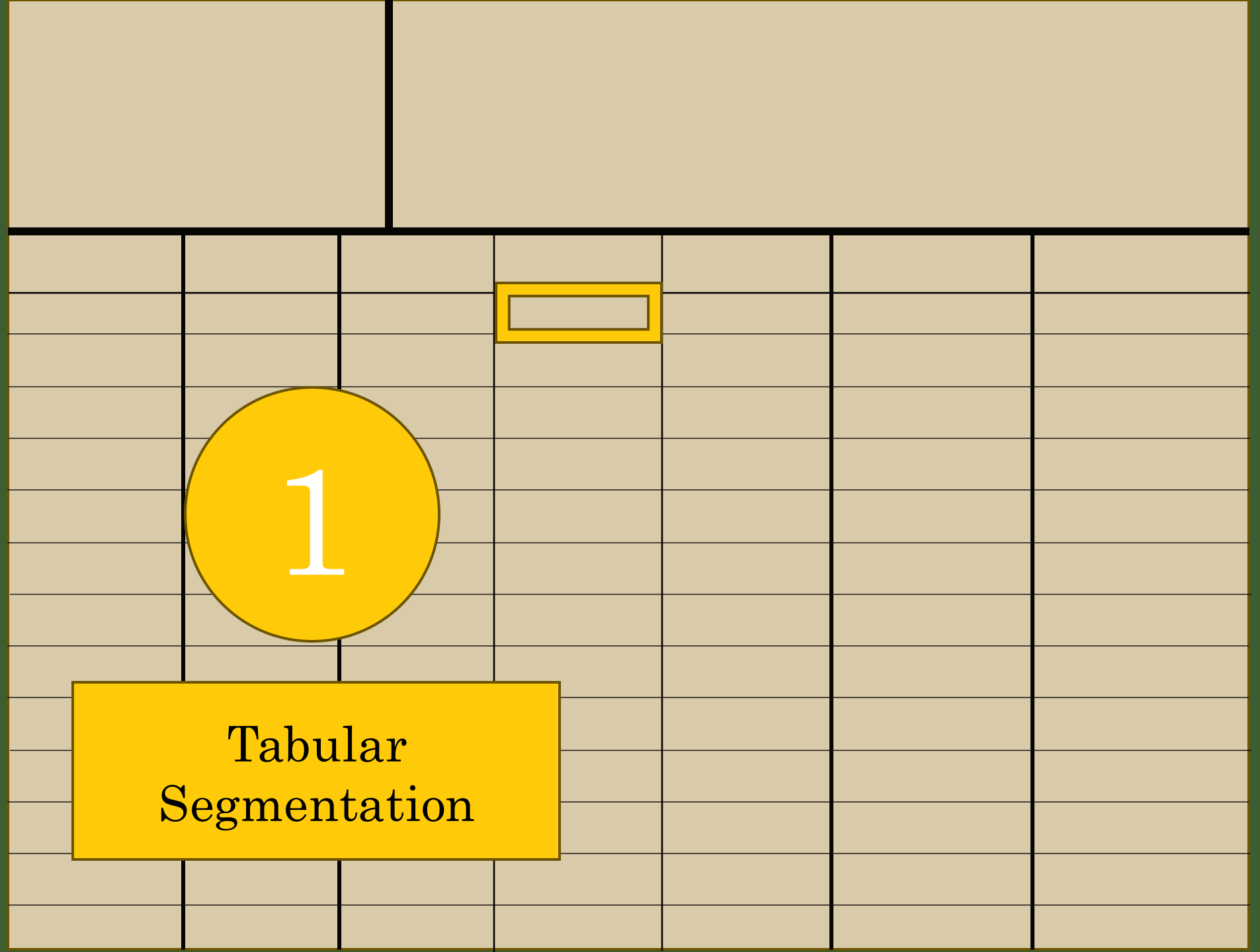
CENSUS TRACT.

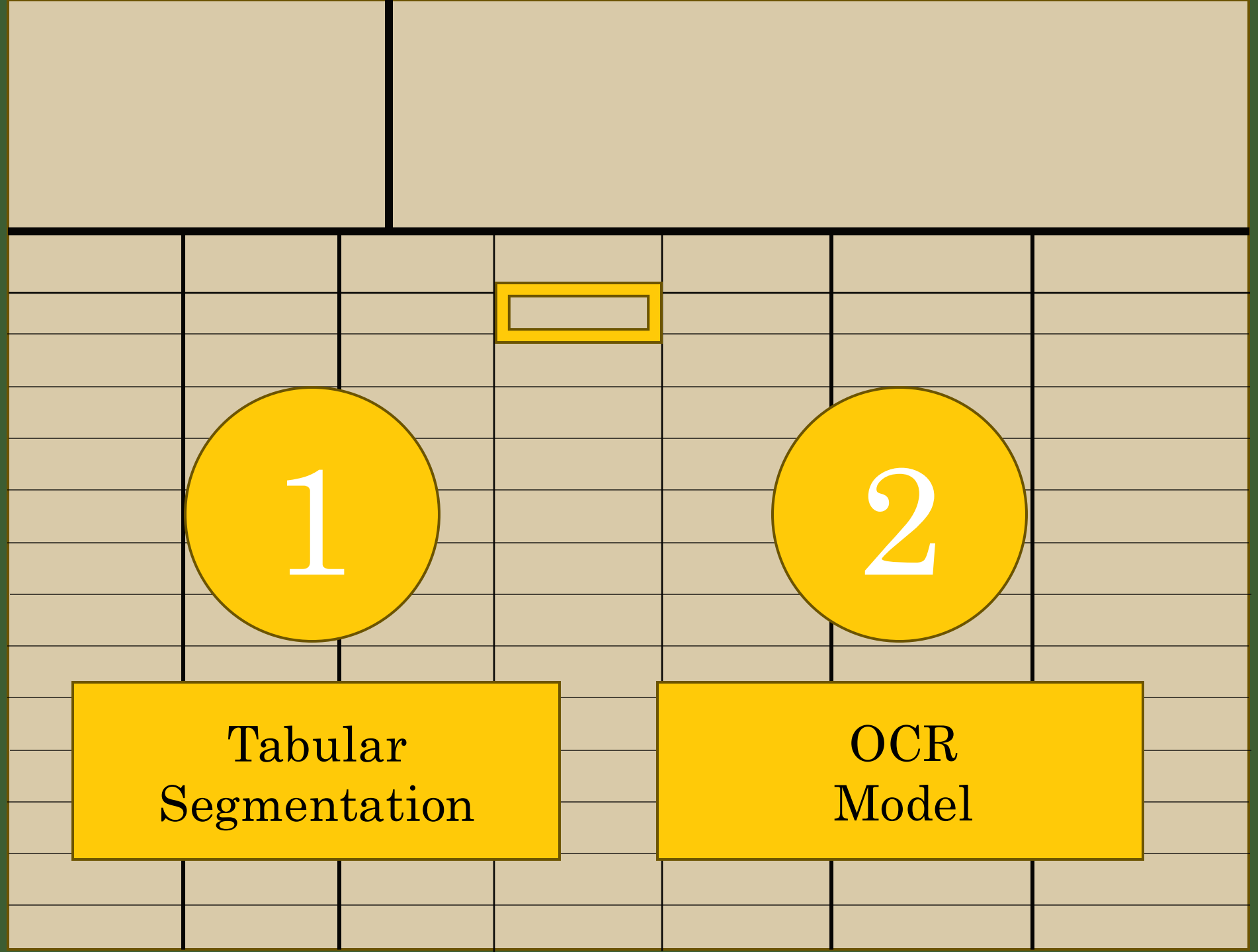
SKETCH OF LAND



REAL ESTATE TAX LIST — GEO. GUCKENBERGER, AUDITOR — HAMILTON COUNTY, O.

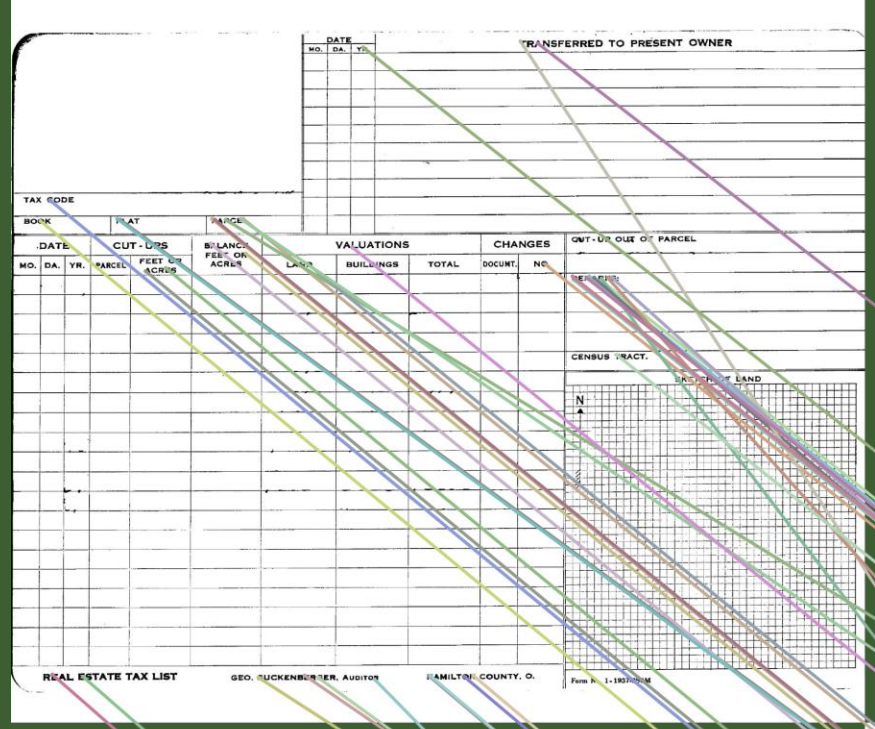
Form No. 1-1937-250M

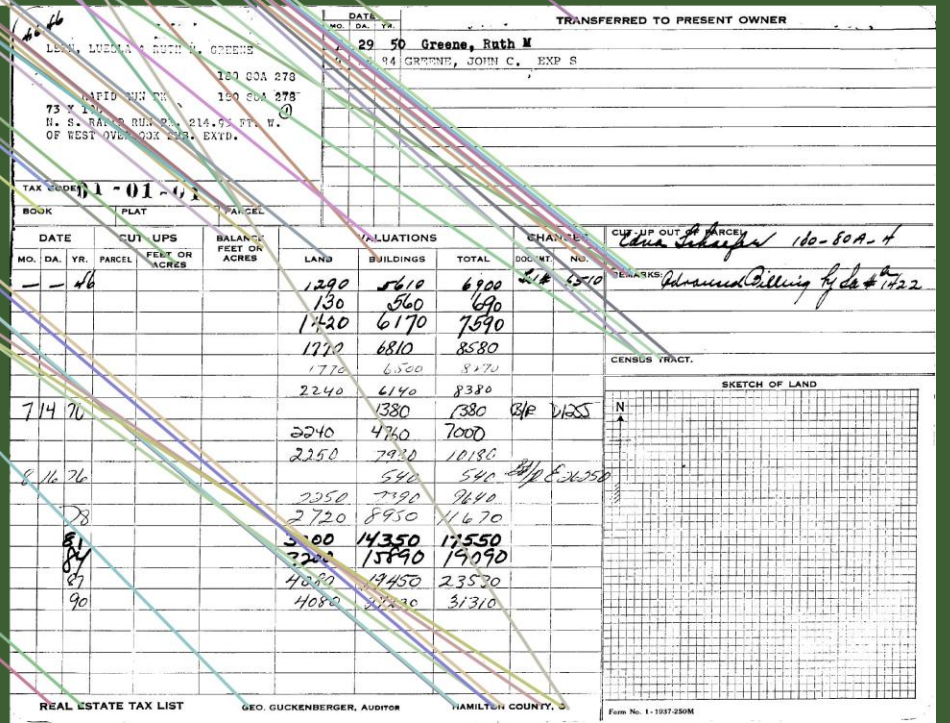

1
Tabular
Segmentation


1
2
Tabular
Segmentation
OCR
Model

1

Tabular Segmentation





2

Detect keypoints, compute descriptors using **ORB**

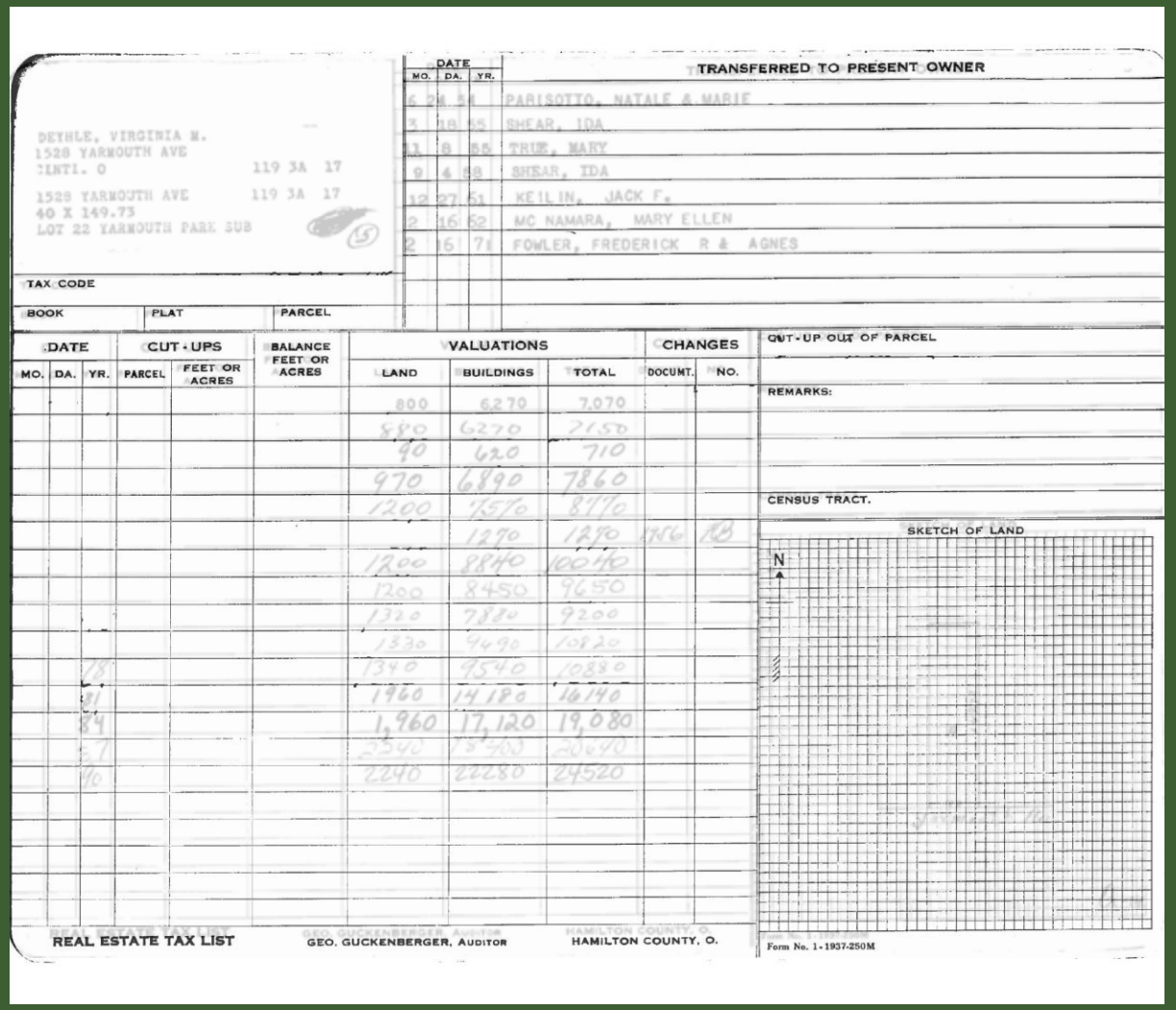
3

Match descriptors with **BFMatcher** and **Hamming distance**, retaining top 5% of 5,000 matches

Filter enforcing quadrant consistency

1

Preprocessing: Lighting conditions taken into account

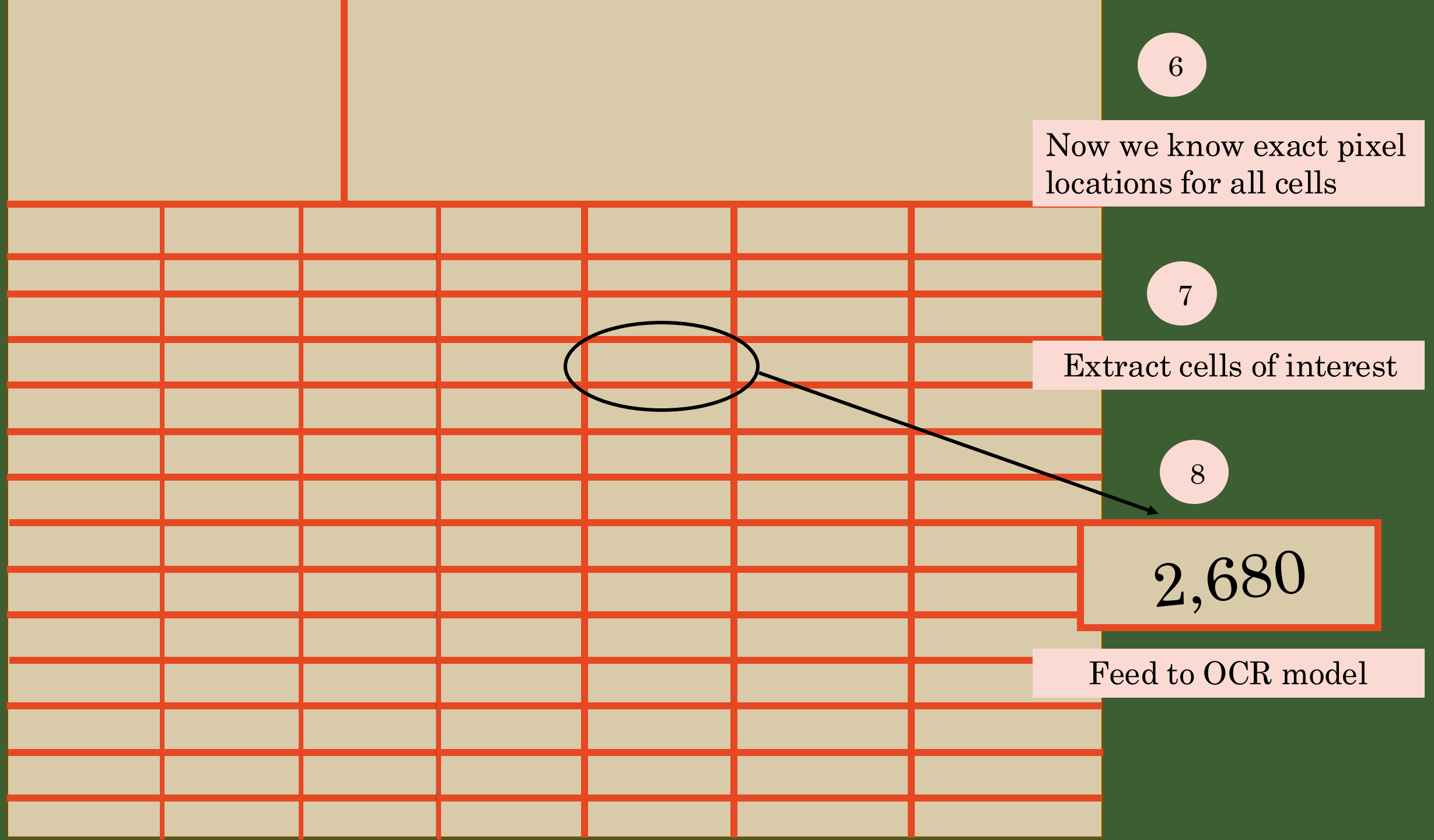


4

Compute **Homography Matrix** from matches with **RANSAC** algorithm

5

Transform image using matrix to align to template!


6
Now we know exact pixel locations for all cells
7
Extract cells of interest
8
2,680
Feed to OCR model

1

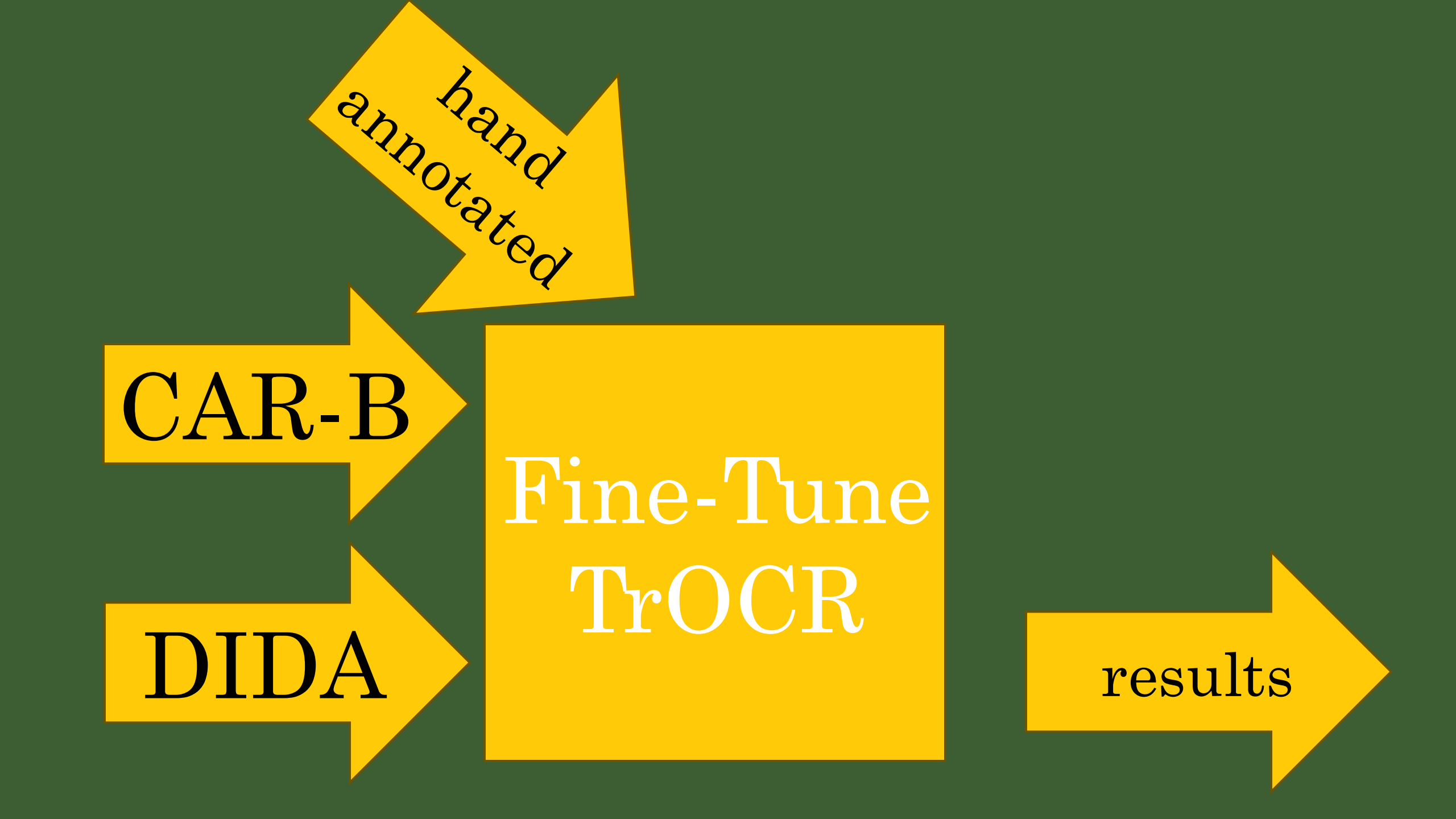
Tabular
Segmentation

2

OCR
Model

2

OCR Model


hand annotated
CAR-B
DIDA
Fine-Tune TrOCR
results

How we evaluate performance

Segmentation

3 Step Alignment

- Homography matrix match count (>15 matches, max reprojection error ≤6px)
- Increase ORB match pairs (5,000 → 7,000 → 10,000) across 3 attempts
- Manual inspection

99.7%

On 836 property cards

How we evaluate performance

OCR Model Results

R^2 (Coefficient of Determination)
How well predicted values approximate actual values.

0.76

MAPE (Mean Absolute Percentage Error)
Average absolute percentage difference between predicted and true values.

3.25%

RMSPE (Root Mean Absolute Percentage Error)
Similar to MAPE but penalizes larger errors more.

36.59%

MPE (Mean Percentage Error)
Indicates bias (over- or under-prediction tendency).

0.36%

How we evaluate performance

OCR Model Results

Confidence-Based Accuracy

Within 5% of True Value	96.52%
Within 10% of True Value	96.98%
Within 20% of True Value	97.38%

Why off-the-shelf solutions failed

Existing Programs

- TesseractOCR
- LayoutLMv3
- LayoutParser
- ChatGPT
- Microsoft Azure AI Document Intelligence

Significantly worse than TrOCR

Poor table cell detection (<20% accuracy)

accuracy

Poor table cell detection (<67 %accuracy)

cost

Very expensive: $1600 for 56,000 cards (just one county)

Why off-the-shelf solutions failed User-friendly GPT4o

Accuracy

Great for **Single-cell OCR** → Matches TrOCR performance
Unreliable for **Whole-card OCR** → Needs heavy prompt engineering

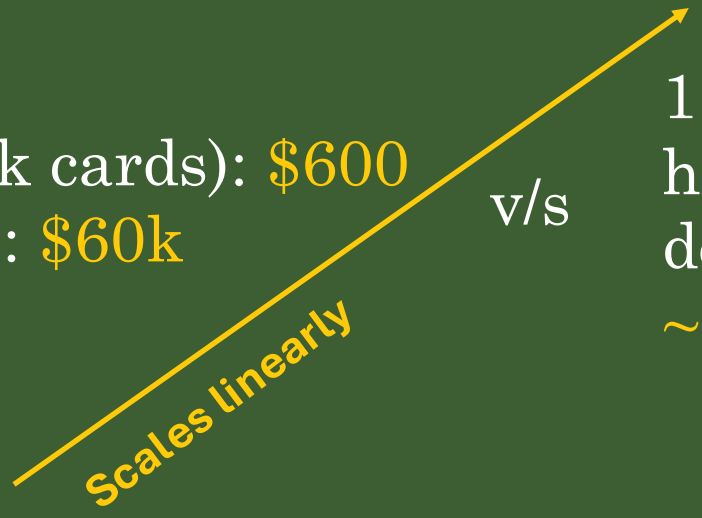
Latency

10–20 sec per image

Cost

Effective for very small datasets
Scales poorly

1 county (56k cards): $600
100 counties: $60k



v/s

1 time investment of hiring for model development: ~$5000

Building Dataset

Predicting Values

Predicting Values

1933

One Story Single Family Homes

square feet	1-bed	2-bed	3-bed	4-bed	5-bed	6-bed
under 100	$1500	$1600	$1700	$1800	$1900	$2000
100-200	$2000	$2100	$2200	$2300	$2400	$2500
200-300	$2500	$2600	$2700	$2800	$2900	$3000
300-400	$3000	$3100	$3200	$3300	$3400	$3500
400-500	$3500	$3600	$3700	$3800	$3900	$4000
500-600	$4000	$4100	$4200	$4300	$4400	$4500
600-700	$4500	$4600	$4700	$4800	$4900	$5000
700-800	$5000	$5100	$5200	$5300	$5400	$5500
800-900	$5500	$5600	$5700	$5800	$5900	$6000
900-1000	$6000	$6100	$6200	$6300	$6400	$6500

1933

Rooms

10

$$y = b_0 + b_1X + b_2X$$

VALUATIONS

BUILDINGS

1,460

Sq. Ft.

850

1933

Rooms

10

$$y = f(b_0 + b_1X + b_2X)$$

VALUATIONS
BUILDINGS
1,460

Sq. Ft.

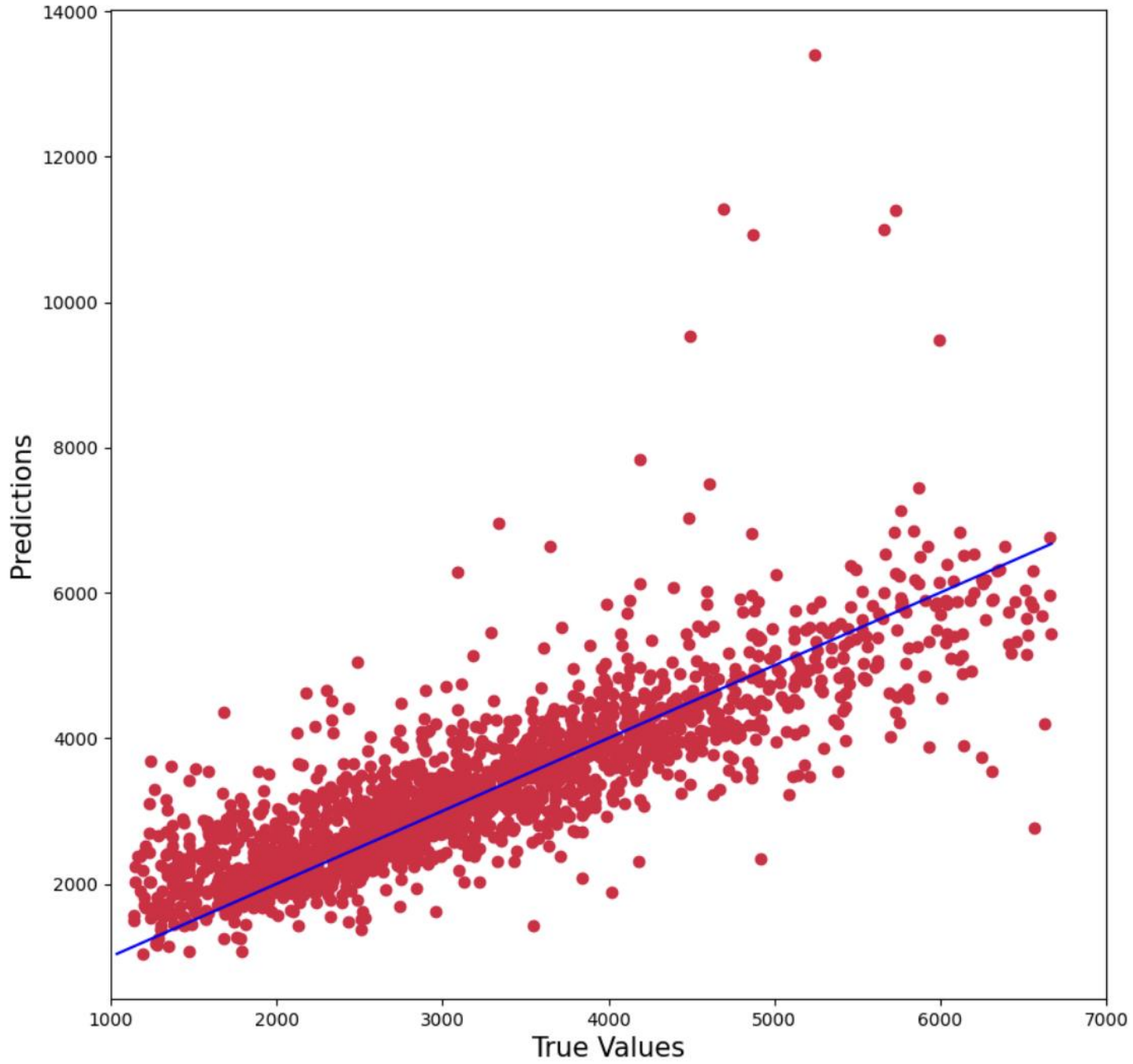
850

VALUATIONS	
BUILDINGS	1,460

VALUATIONS	
BUILDINGS	2680

VALUATIONS	
BUILDINGS	1880

VALUATIONS	
BUILDINGS	2720



R^2 :
0.62

MAPE:
17.5%

OCR MAPE:
14.72%

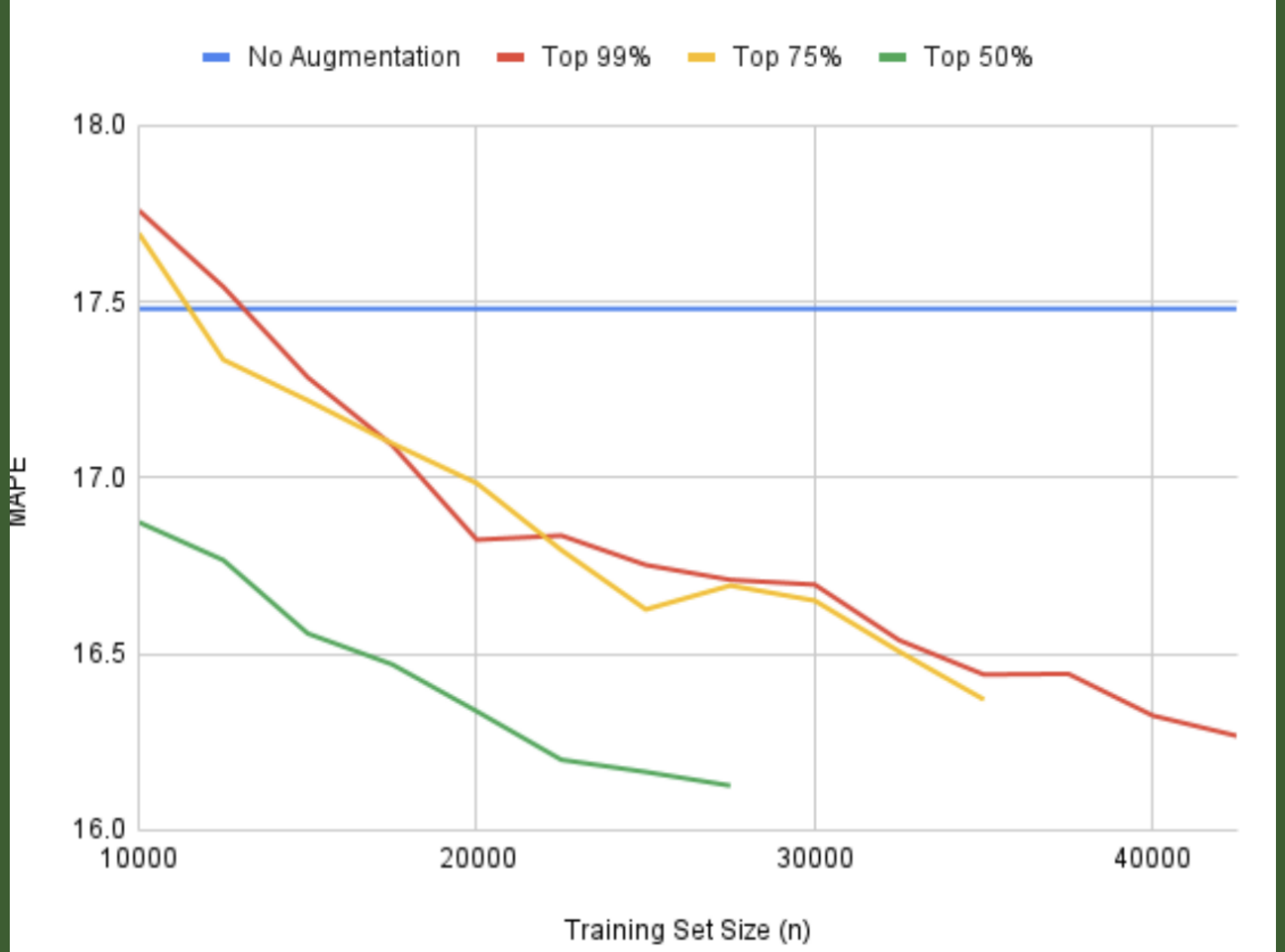
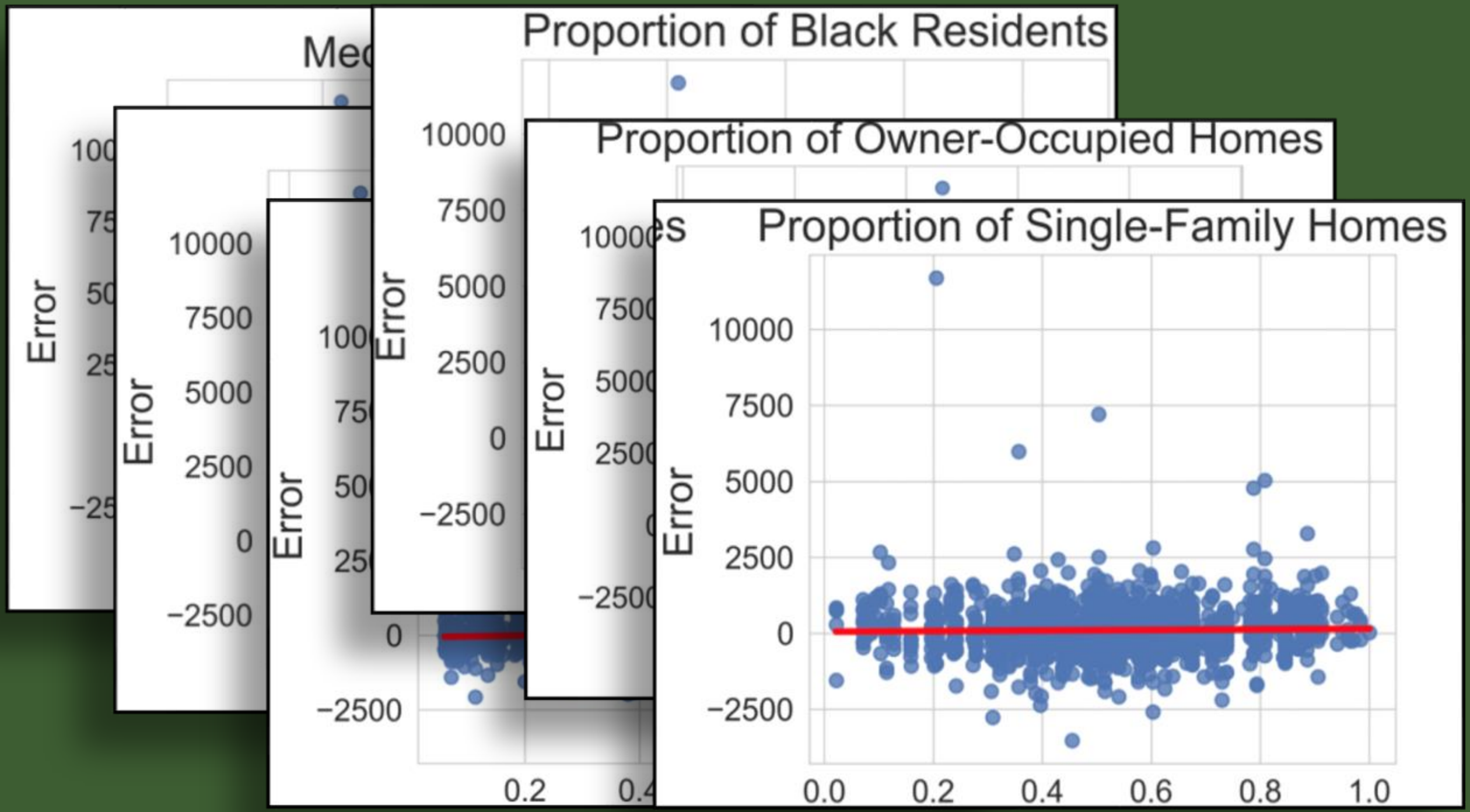
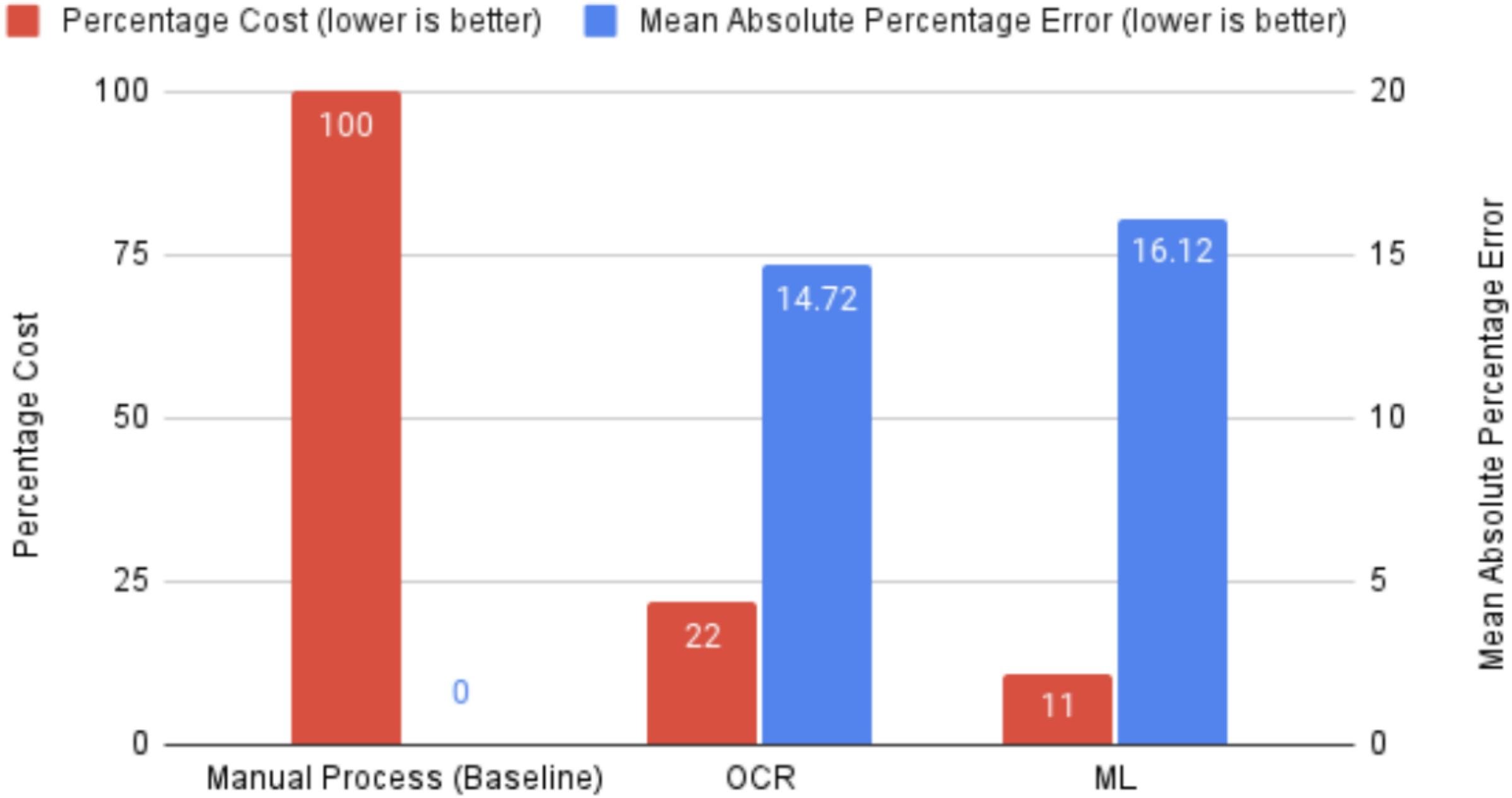


Figure 9: MAPE and OCR Confidence Threshold vs n


Proportion of Black Residents
Proportion of Owner-Occupied Homes
Proportion of Single-Family Homes
Error
10000
7500
5000
2500
0
−2500
0.0
0.2
0.4
0.6
0.8
1.0

Building Dataset

Predicting Values


Percentage Cost (lower is better)
Mean Absolute Percentage Error (lower is better)
100
75
50
25
0
Percentage Cost
20
15
10
5
0
Mean Absolute Percentage Error
100
0
22
14.72
11
16.12
Manual Process (Baseline)
OCR
ML

For More: