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SUSTAINABILITY IN PROPERTY TAXATION: AN APPLICATION FOR REVENUE STABILITY AND FAIRNESS PERSPECTIVES, THE CITY OF BUFFALO, NY

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Abstract. The scholarly modeling of property tax has always posed a challenge, with two primary concerns to be addressed: first, maintaining sustainability in the collection, which is primarily a concern for local governments; and second, ensuring fair distribution, which is of greater concern for citizens. In today's practices, assessment-based property tax increases unmatched expenses in bubble economies. There is a substitution problem in rapid falls, the tendency to not decrease the assessments gives way to black holes and opens the door to ghost cities. This paper proposes alternative approaches, aside from market/land value or last sold price, aimed at improving sustainability and fairness rates. The dataset examined is based on 93.7K records and 88 attributes for assessed value of properties within the City of Buffalo, the United States of America. Since the label (Total Value) is a numerical and continuous value, regression models are selected, where ensemble machine learning methods categorically work well with larger datasets, combined with weak learners, like decision trees. Stacked Ensemble led the least error for regression with 0.98 R^2, followed by Gradient Boosting. Results show a 79% dominance of uncontrollable attributes, such as Land Value, Neighborhood, and Sale (last sold) Price, compared to controllable attributes, such as Total Living Area, Construction Grade, Second Story Area, and many others. This article suggests having a more balanced split between uncontrollable and controllable attributes would contribute to both sustainability and fair distribution.

Keywords: property tax, sustainable property taxing, tax revenue stability.

Introduction

Property tax has long been popular scrutiny for scholarly analysis, and traditionally there have been two main challenges in securing its effectiveness. The first is to maintain sustainability concerning collections, which is more of a concern for local governments. The second challenge is to ensure fair distribution, which is more of a concern for citizens. Sustainability comes twofold. First, accounting for 80% of all taxes, property tax is a crucial revenue source for local governments, however, there is no apparent substitute that makes it hard to mitigate. In addition to that, most of the property tax is based on market value assessment, which jeopardizes future stakes, when the market favors buyers, resulting in less income (Anderson, 2006; Cornia & Walters, 2006). Fairness perspective when the market favors sellers, this is disadvantageous for homeowners who pay higher property taxes during a period of inflated prices where the price level has not yet been capitalized, thus blatantly violating the sense of justice (Tsoodle & Turner, 2008; England, 2016; Liberati & Loberto, 2019). The comparison can be mimicked with taxing investors on stock price increases without any capital gains realized, as there are no sales yet. This is not ideal for renters too, since the tax increase needs to be reflected as a large chunk rather than a few percentages each year as usual. The reason for the tendency to use market value assessment as a primary source is the historical limitations with data, as there is no other data that drives real estate transactions regularly. However, with the advent of big data, a variety of attributes, such as construction grade, overall condition, heat/fuel type, and number of beds/baths/kitchens are now available to also make it a part of predictions.

This paper proposes alternatives other than market/land value or last sold price, to improve sustainability and fairness rates in property tax collection, to please both local governments and citizens.

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Assessment-dominated property taxing increases impulse spending in local economies and leads to weak budget performance with shrinking cities. There is a substitution problem that causes local government to act even more protectively (Pokrovskaia & Belov, 2020; Accordino & Johnson, 2000). What is being interpreted by stability is to apply the same policies in respect to Total value for decades, however policies cannot yield a stable outcome, since they are heavily dominated by uncontrollable elements, like assessment value. This fundamental juxtaposition is reaffirmed as a justification of the paper and layout the foundation primarily for 1.2-to-1.6. Also, the definition of stability as a verbiage is revisited as a part of contextual limitation within the Implications section. Short-term stability and long-term stability are not the same, as a matter of fact, the former does not necessarily make a predecessor (Markus & Paffendorf, 2022). Knowing that sustainability hypothetically threatens long-term objectives, to not jeopardize the short-term gains, it would be fair to note that local politicians would take it out of sight, as they can. Policy makers may need to consider this ontological problem and may want to have more direct involvement for a more complete solution.

1. Property tax share in local government revenue

Property taxes are a vital source of income for local governments, all over the world. As primarily the number one source, they often play a crucial role in supporting schools, infrastructure, healthcare, and public safety. The percentage of property taxes as a local government generator varies across countries, states, counties, towns, cities, and municipalities. In the United States, property taxes make up 34.2% of local government income nationally.

In the United Kingdom, according to the UK Ministry of Housing, Communities, and Local Government, property taxes accounted for around 32% of local government income, whereas other revenue generators are business rates, council taxes, funds from central governments, and service charges (Vlassenko, 2001; James, 2012).

Across Europe, local government revenue systems vary from country to country. While property tax leads in many countries, other revenue sources for local income in Europe include sales taxes, income taxes, charges, intergovernmental transfers, and European Union grants. In Germany, property taxes, namely "Grundsteuer", has relatively a modest contribution to local government revenue, 13% to 16% of local government income, according to data from the Federal Statistical Office. In France, property taxes, known as "taxe foncière" (land tax) and "taxe d'habitation" (residence tax), contribute more, with 19% to 22%, to local government revenue, according to the French Ministry of Economy and Finance. In Spain, similar to France, property taxes, namely "Impuesto sobre Bienes Inmuebles" (IBI) and "Impuesto sobre el Incremento de Valor de los Terrenos de Naturaleza Urbana" (IIVTNU or municipal capital gains tax), contribute 15% to 20% of local government revenue, where Italy does not make an exception (Almy, 2001; Reshetov et al., 2020).

In Japan, local government income mainly comes from grants (called "chihō-josei") from the central government. Property taxes, including fixed asset and city planning taxes, make up 21% of local government revenue, whereas income taxes, business taxes, and consumption taxes also contribute as revenue generators, according to data from the Ministry of Internal Affairs and Communications (Unel & Yalpir, 2023).

In Turkey and Brazil, as atypical examples, property tax is 0.5% of assessment value in average, one of the lowest in the world and make only 6%-to-8% of local government revenue. There are some attempts to teach per past data and predict per mass appraisals, with modest standard deviations, however it is far from addressing the problem which is the opposite of the world; the property taxing is not being represented enough in local revenues (Miotti & Loch, 2021; Sagaydak & Sagaydak, 2021). Russia also shares the same underrepresentation with a starting rate of 0.3%, however they have a very high home ownership with 91%, therefore there is no indirect cost for renters, unlike Turkey and Brazil (Stojanov et al., 2019).

Overall, the United States has one of the highest dominances for property tax in total local government revenue, with a share of 34.2%, almost double of some countries like Germany and Spain, which deserves scrutiny concerning healthier taxing systems.

1.1. Detailing – the United States

In a larger sense, property taxation is a matter of jurisdiction and overall taxing policies. In practice, it comes twofold, it widely depends on the local economy's needs, and how diversified are the revenue sources and population. Per needs assessment perspective, in the United States, school district leads the property tax collection as a need, where it only makes up 37% of the needs of school districts, where Township heavily depends on Property Tax with 62%, although the need itself is relatively small, as shown in Figure 1 (Harris et al., 2013; Urban Institute, 2017 and 2020a).

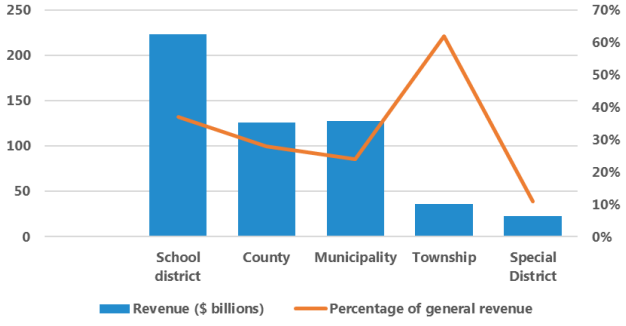

Figure 1. Property tax collection per need and its share in need, the United States (Urban Institute, 2017)

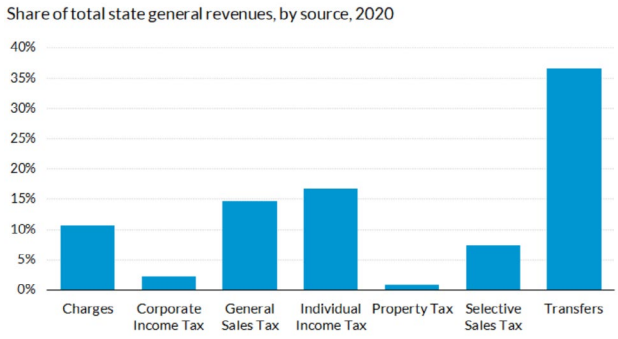

Figure 2. Sources of state revenue (Urban Institute, 2020b)

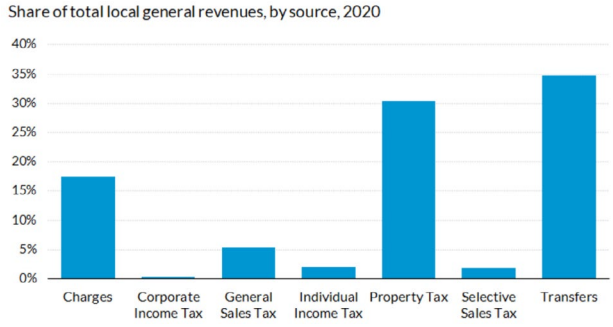

Figure 3. Sources of local revenue (Urban Institute, 2020b)

From a resource distribution perspective, it would not be wrong to note that, in many cases for many different countries, property tax leads to the local governments' income. In the United States, local income is being utilized to fund local services and needs that vary from schools to infrastructure, public safety to overall healthcare, where it is being dominated by property taxes with 34.2%, amongst all other revenue generators, such as sales taxes, fees, service charges and intergovernmental grants such as transfers from the state and federal offices, as shown in Figures 2 and 3 (Urban Institute, 2020b; Fleck et al., 2021; Artige & Cavenaile, 2023).

Most transfers in local revenue are being capitalized by state revenue, whereas the vast majority of transfers in state revenue being capitalized by federal revenue:

- Federal revenue: About 50% of federal revenue comes from individual income taxes, 36% from payroll (social insurance) taxes, and another 7% from corporate income taxes.
- State revenue: Federal revenue attributes are either not or slightly represented within the state and local own-source revenues, excluding transfers. Individual Income Tax, General Sales Tax, and Charges (tuition, tolls, payment to public hospitals) dominate the state's own-source revenue.
- Local revenue: State revenue attributes are either not or slightly represented within local own-source revenues, excluding transfers. Property Tax (34.2% of total, 47% of own-source) and Charges (primarily sewerage and parking fees) dominate the local own-source revenue.

1.2. Where's Waldo: is Corporate Income Tax being underrepresented in federal revenue

Although property tax weight on state and local (where primarily affects the local side) revenue decreased by 24% thru the years from 1977 to 2020, as shown in Figures 4 and 5, with 34.2% dominance on total and 47% on own-source local revenue of one-and-only source, a single-source, still hypothetically jeopardizes future stakes as a sustainable income generator (Urban Institute, 2020c; Boddupalli et al., 2021). Meanwhile, Corporate Income Tax weight also decreased to its half, with only a 2% share, almost 10% of property tax's contribution to total revenue. Notably, it is being compensated by federal transfers, however, we already reviewed that only 7% of federal funds are being generated by Corporate Income Tax (Boddupalli & Rueben, 2021; Dadayan & Rueben, 2021; Auxier & Weiner, 2023).

1.3. Verdict: 25%-to-5% in 70 years

Federal tax income historically has a 17.4% average of GDP through the years, from 1969 to 2019, with no major fluctuations (Office of Management and Budget, 2017a). According to the Office of Management and Budget, the total Corporate Income Tax and Excise Tax weight dropped to only 6%, from 45%, in the last 70 years, as shown in Figure 6 (Office of Management and Budget, 2017b; Sherlock & Marples, 2018). After all, revisiting federal revenue sources validate that Corporate Income Tax, as well as Excise (cigarettes, alcoholic beverages, gasoline, and airline travel) Tax, are relatively under-represented for all income levels, Federal, State, and Local, however,

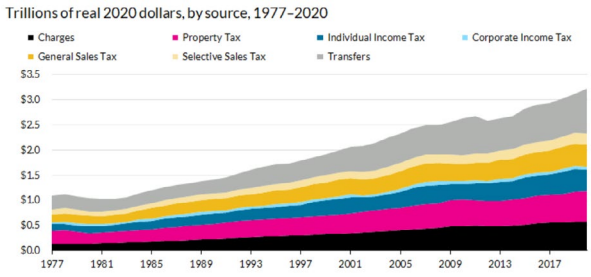

Figure 4. State and local revenue, $ (Urban Institute, 2020c)

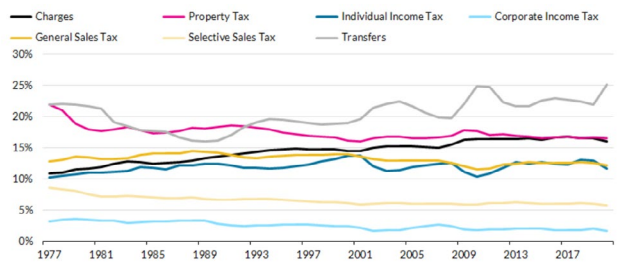

Figure 5. State and local revenue, % (Urban Institute, 2020c)

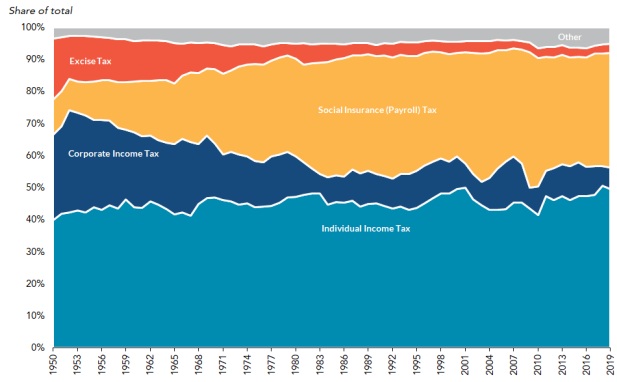

Figure 6. Sources of federal revenue, %
(Office of Management and Budget, 2017b)

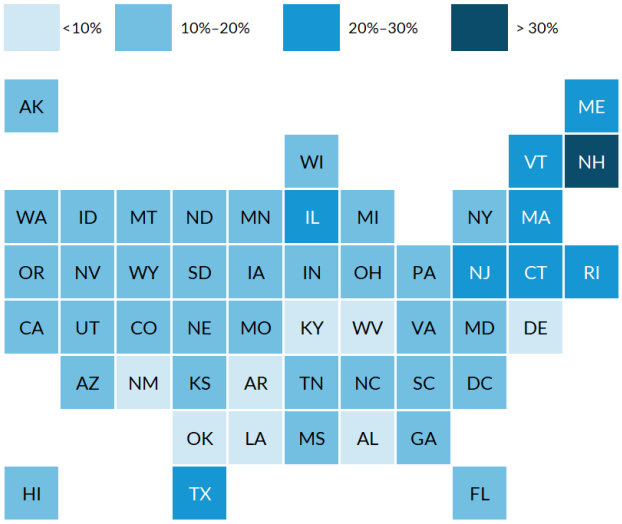

Figure 7. Property tax revenue, share of state and local
(Urban Institute, 2020d)

it creates the major pain for local revenues, since it makes the Property Tax number one with 47% dominance for own-source local revenue, which ultimately jeopardizes sustainability. To sum up, the under-representation of the total Corporate Income Tax and Excise Tax (45% to 6% in federal income distribution) deserves scrutiny, since some components (like Property Tax in local income distribution) take the pressure unproportionally and increase risks with continuity. Payroll tax is another one, with state income, however, it is not all alone, still a follower after individual income tax. It is also notable that Corporate Income Tax is the most major attribute that relates to federal income. Knowing that other components (Individual Income Tax and Payroll Tax) are being accounted for by individuals, it is difficult to not question why corporations are lagging with the modest and decreasing contributions possible, for any level, as a federal, state, or local revenue income generator, and how they can manage their ghost presence without any further inquiry (Tax Policy Center, 2019; Gürlek, 2021).

1.4. Variations

Furthermore, in the United States, local governments are represented by counties, cities, and towns, rather than only states, and taxing, including property taxing, differs from municipality to municipality (Harris et al., 2013; Youngman, 2016). Property tax makes up 17% of the total income for state and local, and 34.2% for only local. Knowing that state and total revenues are $2Billion each and the state does not have property tax as a significant source, it is understandable that it is doubled up for local. For instance, New Hampshire leads the weight for property tax with 34% for state and local, 40%-to-60% for only local, as shown in Figure 7. Please note that New Hampshire does not have a regular stream for individual income tax or general sales tax. There are 9 states above average, where New Jersey makes 29% for state and local combined, Connecticut, 26%, and Maine, 25%, as leading states (Urban Institute, 2020d; Amornsiripanitch, 2020; Berry, 2021).

New York has the average with 17%, where locals vary, for instance, New York City has property tax dominance with 44%. There are 62 counties, 933 towns, and 61 cities in New York State. Some cities share the same metrics as the United States, 34% share in local income, whereas the City of Buffalo also publishes extensive data with 88 attributes and 93.7K records.

1.5. Property tax dynamics

Property taxes are mostly based on assessment values, where assessment values are variations of market values. In some countries, it is calculated in a centralized way, national level, in some countries it is decentralized, it is calculated by local governments. In some countries, it is hypothetically volatile with no tangible (like property size or premium brackets) specifications, in some countries it is a combination of tangible elements. However, what makes the real difference is whether a tax levy, like in the United States, is a part of the equation or not. The percentage can vary depending on the state, city, county, and town, with rates typically ranging from 0.5% to 2.5% of the assessed value, where it is rarely less than the market price.

In the United Kingdom, property taxes are council tax for residential properties, whereas business rates are for others. It is decentralized per country but centralized within the country. Key elements include valuation, tax banks, and multipliers (Ushatova, 2019). Valuation is being managed centric in England, by the Valuation Office Agency (VOA), and like the US, it is primarily referenced to market value. However, tax bands and multipliers balance the council rates and volatility accordingly. The tax rate is typically under 1.5%.

In Europe, property tax systems can vary from country to country. For instance, Germany has a decentralized approach where local jurisdictions set property tax rates. France and Italy, have more centralized systems, and tax rates are mainly managed nationally (Kelly et al., 2020).

Formula-wise, unlike the US, market value-based assessment is not the sole attribute, it is usually combined with factors such as size, and location. Property tax rates in Europe can range from 0.2%-to-2% of the property's assessed value. The typical tax ratio as one of the lowest, 0.2%, of some countries, like Turkey, is the entry bracket for many other countries. However, it is followed by an additional 1% tax band for premium properties.

Like Italy and France in Europe, property tax rates in Japan are also set nationally. The collection is being performed by local governments; however, rates are set by the national tax laws and the central government applies across the country. Tax rates can vary on the municipality, it usually ranges from 1%-to-3% of the assessed value, however, the assessed value is usually lower than the market value.

Overall, there are a couple of characteristics in property tax determination in the world. Concerning tax ratio averages, world practices have more similarities rather than differences. Also, for most countries, it is assessment based. However, unlike the US, it is usually lower than the market value, and/or it is not the sole attribute, it is balanced with other factors, like size and location, to maintain subjectivity (Propheter, 2022). It is also often being assessed by central governments, even though it is being collected locally.

1.6. Tax levy

In simplest terms, tax levy shows the budget deficit. In other words, it is the difference between the local government's needs and the revenue other than property taxes (which is state transfers, as well as charges), expecting property taxes would compensate the leftover (Brien, 2018). When this is the case, property taxing simply turns to funds raising, rather than formula-based assessments, since it creates a dependency with no substitute, where the United States is one of those countries. For example:

- Jurisdiction's tax levy = $10,000,000 [Tax levy = Budget/Needs – Revenues].
- Jurisdiction's total taxable assessed value, per local's assessment = $1,000,000,000 [Tax rate per 1,000 = (tax levy ÷ total of all taxable assessments in jurisdiction/town) x 1,000].
- Tax rate = $10 per $1,000 of taxable assessed value.
- The tax bill for a property with a taxable assessment of $500,000 = $5,000, approximately 1% assessment/market value.

To mention a few problems with this representation:

- Property tax is positioned as a last resort: If the budget deficit, a.k.a. tax levy, is doubled up, the tax rate, as well as tax bill/ratio would also need to be doubled up, which should typically not be applicable. This will yield a revisit of state transfers and charges and will initiate a vicious cycle (Radvan, 2019).
- Overdependency on assessment value has double jeopardy: Needs rarely go back, however, market values can, as we had many times through bubble economy crashes. When it happens, overdependency on assessment value per property tax puts local governments in a situation with the extra pressure that they cannot apply the drop in assessment values. The pressure on property tax can technically quadruple the tax ratio, and with the same example, 8% as a tax ratio can suffice to create ghost cities in the time being and lead to black holes with zero tax. After all, we should also remember that taxing homeowners per inflated prices where the price level has not yet been capitalized, since there are no sales, thus also blatantly violating the sense of justice. This will create a one-sided relationship with no apparent future for any party (McMillen & Singh, 2020).
- Budget/Needs seem to have no upper limits: If we allow the budget to be unpredictably volatile, it will accordingly require a volatile element, e.g., property tax, in a way that is being perceived. Any fluctuation significantly more than the inflation rate would be unrealistic and will lead to a causality dilemma (Barnett & Vidal, 2013).

1.7. Inter-state level and beyond

The state-level analysis made clear that inter-state tax ratio differences are mostly dominated by school performance, however, it is not a part of the assessment directly. When the school does not explain, simply a lack of resources would be the reason for higher taxes.

- New Jersey is the number state concerning high tax, both ratio and amount (2.47% and almost 5 figures in dollars) wise, where it is also the only one where the lowest bracket (1.5%) is more than the national average, which is 1.1.%. New Jersey is also one of the few states that represent both good school districts (Princeton, Montgomery) and simply just lack of resources (Newark, Roselle) as reasoning, where sometimes the latter has even more tax ratio (Gallagher, 2019).
- Tax ratio wise, 2%+, New Jersey is followed by Illinois with much less average house sales prices, besides New Hampshire and Connecticut with much less crime rates (Shertzer et al., 2022).
- Texas and New York seem to hit 1%-to-2% as large states, with some nationally ranked public schools in New York City, although the city lags the property tax ratio with 0.88% (Rumbach et al., 2022).
- Heaven on Earth, one of the smallest states, Hawaii is number one with the lowest tax ratio, coupling with the highest average house sales price, which is followed by one of the largest states, California with similar high average house sales price vs low tax ratio metrics, with not necessarily bad public schools (Kulkarni & Malmendier, 2022).

1.8. New York State and beyond

New York State's property tax share per market value was only a few points per thousand once, back in 1850. Remembering our early notes, what makes New York special

comes threefold (Schwab, 1890; Arsen, 1992). New York represents the national average with 17%, concerning property tax share in state and local revenue. There are 62 counties, 933 towns, and 61 cities in New York State, and there are some cities that share the same metrics as the United States, 34% share in local income, where the City of Buffalo also publishes extensive data with 88 attributes and 93.7K records. Second, New York's property tax ratio is relatively close to national averages, it's 1%-to-2%. Third, unlike New Jersey's counties, and cities, when one has a high tax ratio, there is usually a reason, it is not just a lack of resources, it is usually the school district. The upper-end counties, like Suffolk County with a tax ratio of 2.8%, Erie County (linking to the City of Buffalo) with 2.65%, and Westchester County with 2.5%, have all great schools to justify it accordingly. It must refer to utilization efficiency since the ultimate objective of this study is not how to decrease property taxes, it is how to favor sustainability in property taxes (Eom, 2008; Hayashi, 2014, 2020; Sarkar & Rosenthal, 2018). (Not because the former is not an issue for some jurisdictions, collecting property taxes to compensate for lack of resources, with no apparent benefits, would make a very important issue, however, it can be addressed with a different dataset.)

2. Data discussion

The City of Buffalo is one of the very few cities that represent the United States averages concerning the share of property tax in local revenue, as well as publishes raw data, not only summary tables; they also promote Open Data Policy, since August 2017 (City of Buffalo, 2023). Being a data-smart city, they are receptive to new contributions from many different parties. In their own words, the researcher's perspective was explicitly exposed as "… whereas, making open data available online for reuse and consumption creates value for residents, government leaders, businesses, researchers, and the media, and facilitates the proactive provision of information currently sought through Freedom of Information Law requests…". There are 93.7K house observations with 88 attributes, where the full list can be found in Appendix Table A1.

3. Methodology

Out of 88 attributes, the Total Value (Assessed value of the parcel) was selected as the label. The data cleansing job included the elimination of 30 columns, which yielded 58 columns to work with. Typical problems were categorized as uniqueness, parsimony, multicollinearity, and irrelevancy.

- Uniqueness problem: Unique values cannot make a factor, such as SBL.
- Parsimony problem: Too many instances per column, such as Deed Date, Deed Page, Deed Type Code, GEOID20_block, GEOID20_blockgroup, GEOID20_tract.
- Multicollinearity problem: Repetitive information with variations of columns, such as Address Bill Number, Council District Abbreviation, Description 1, Description 2, Description 3, House Number, Latitude, Location, Longitude, Mail Country, Mail Zipcode Extension, Mail1, Mail2, Mail3, Mail4, Print Key, Special District Code, Street, Used as Code, Zipcode Extension.
- Irrelevancy problem: No utilization per irrelevance and further privacy, such as Owner 1, Owner 2, Previous Number.

Out of 93.7K records, nearly 36K observations were deleted due to too many missing cells, which yield 56.7K records with 58 columns, with 29 categorical and 29 numerical values, where one is spared as a label, it is Total Value, the assessed value of the parcel.

Since the label (Total Value) is a numerical and continuous value, regression models are selected with variations of mathematical methods. Compared to linear methods, ensemble machine learning methods work well with larger datasets like we have here, tens of thousands of observations with tens of attributes; it combines weak learners, like decision trees (Buodd & Derås, 2020; Hong et al., 2020). Typically, ensembles have variations, primarily Random Forest, Stakes Ensembles, and Gradient Boosting Machine (GBM) are the most popular learners, a.k.a. super learners. Amongst many parameters, a few selected can be mentioned as max_runtime_sec=60, seed=1, split_frame (ratios=[0.8]) (Chen et al., 2017; LeDell & Poirier, 2020).

4. Analysis – results

Quick data descriptions for a few selected numerical attributes can be found in Table 1. The standard deviation is high for almost all attributes, 25% on average. For Sales Price, Land Value, and Total Value standard deviation is almost 100%, which favors domination as an important factor.

The heatmap in Figure 8 consists of nearly all attributes, including our label, Total Value.

- Total Value seems very insightful, having a very significant positive correlation with Land Value, and several moderately positive correlations with almost half of the attributes. No very significant negative correlation with attributes is observed.
- Council District, Police District, and Neighborhood have very significant positive correlations with Tax District, Zipcode, Census Tract, SWIS, and TRACTCE20 (The six-digit 2020 census tract of the parcel).
- Similarly, Property Class Code seems to have a significant correlation with many attributes, including # of Stories, Fireplaces, Beds, and Baths.
- Negative correlation perspective, SWIS (The 6-character numeric code that uniquely identifies each county, city, town, and village within the State of New York) seems to dominate with many attributes including # of Stories, Fireplaces, Beds, and Baths. Tax District has a very significant positive correlation with TRACTCE20 and Census Tract (The 2010 census tract where a parcel of real property is located), as shown in Figure 9.

Table 1. Summary data

Attributes	Type	Mins	Mean	Maxs	Sigma
# of baths	real	1	1.619105	7	0.609532
# of beds	int	0	4.113714	12	1.360179
# of fireplaces	int	0	0.155818	7	0.458396
# of kitchens	int	1	1.463578	3	0.542518
# of stories	real	1	1.767991	3	0.364493
Acres	real	0	1.259617	14215	133.4109
Add area	int	0	3.650489	2027	62.45391
Attic area	int	0	47.35929	1410	114.4992
Basement type	int	1	3.622655	4	0.795704
Building style code	int	1	7.650577	15	1.769656
Census block	int	1000	2338.534	7005	1251.467
Census block group	int	1	2.333744	7	1.251934
Census tract	real	1.1	51.68532	171	42.8954
Central air	int	0	0.077424	1	0.267276
CONSINCVAL	int	0	120.1973	246500	3365.434
Deed book	int	966	11190.86	40920	426.6234
Depth	real	0	118.5075	630	40.01994
Exterior wall code	int	1	2.760328	8	1.103874
First story area	int	0	1097.775	4049	307.1535
Front	real	0	36.55829	190.47	12.50444
Fuel type	int	2	2.009943	4	0.11881
Heat type	int	1	2.076191	4	0.412445
Land value	int	1	16191.91	337000	27194.17
Overall condition	int	1	2.983441	5	0.371994
Previous property class	int	210	217.4743	483	20.62851
Property class code	int	210	217.4743	483	20.62851
Roll	int	1	1.021580	8	0.388084
Sale price	int	1	69073.37	1440000	104570.2
Second story area	int	0	619.9782	4049	559.0888
Total living area	int	1	1871.337	8098	699.7637
Total value	**int**	**1700**	**112642**	**1160000**	**106900**
Year built	int	1801	1918.969	2021	24.59197

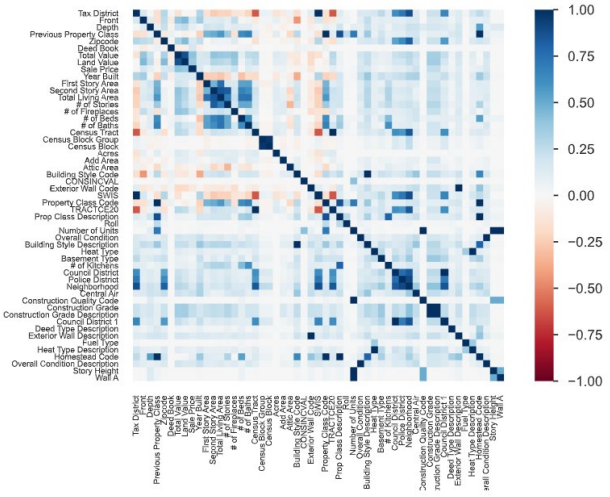

Figure 8. Heatmap

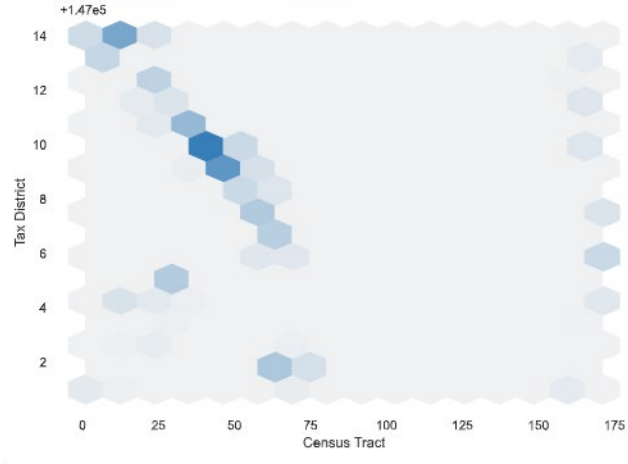

Figure 9. Tax district – census tract interaction

Table 2. Leaderboard – top 10

Model name	RMSE	MSE	MAE	RMSL	Mean residual deviance
StackedEnsemble_AllModels_3_AutoML_1	21656	4.690e+08	11685	nan	4.6901e+08
StackedEnsemble_AllModels_1_AutoML_1	21716	4.716e+08	11765	nan	4.7160e+08
StackedEnsemble_AllModels_2_AutoML_1	21727	4.720e+08	11773	nan	4.7208e+08
StackedEnsemble_BestOfFamily_3_AutoML_1	21951	4.818e+08	11786	0.1761	4.8186e+08
StackedEnsemble_BestOfFamily_2_AutoML_1	22036	4.855e+08	11680	0.1737	4.8559e+08
GBM_4_AutoML_1	22221	4.937e+08	12101	nan	4.9378e+08
GBM_3_AutoML_1	22329	4.985e+08	12464	nan	4.9859e+08
GBM_grid_1_AutoML_1	22510	5.067e+08	11964	nan	5.0674e+08
GBM_5_AutoML_1	22733	5.168e+08	12391	nan	5.1681e+08
StackedEnsemble_BestOfFamily_1	22754	5.177e+08	12340	nan	5.1778e+08

Table 3. Performance metrics

Metrics	Train	Validation
MSE	1.85E+08	4.69E+08
RMSE	13595.88	21656.84
MAE	8623.63	11685.93
RMSLE	NaN	NaN
Mean residual deviance	1.85E+08	4.69E+08
R^2	0.984037	0.958174
Null degrees of freedom	10040	5802
Residual degrees of freedom	10033	5795
Null deviance	1.16E+14	6.51E+13
Residual deviance	1.86E+12	2.72E+12
AIC	219644	132350

Table 4. Important variables – top 20

No	Variable	Relative importance	Scaled importance	Percentage
0	Land value	1.06E+15	1.000000	0.492528
1	Neighborhood	5.98E+14	0.562999	0.277293
2	Total living area	8.53E+13	0.080351	0.039575
3	Construction grade description	7.93E+13	0.074625	0.036755
4	Construction grade	5.24E+13	0.049327	0.024295
5	Sale price	3.62E+13	0.034080	0.016785
6	Second story area	2.59E+13	0.024356	0.011996
7	Overall condition	1.95E+13	0.018389	0.009057
8	# of baths	1.88E+13	0.017702	0.008719
9	Overall condition description	1.51E+13	0.014215	0.007001
10	Prop class description	1.48E+13	0.013980	0.006885
11	SWIS	1.27E+13	0.011912	0.005867
12	Building style description	1.26E+13	0.011863	0.005843
13	Year built	1.23E+13	0.011604	0.005715
14	# of fireplaces	1.23E+13	0.011538	0.005683
15	Zipcode	1.15E+13	0.010859	0.005349
16	Tax district	8.45E+12	0.007958	0.003919
17	First story area	8.17E+12	0.007690	0.003787
18	TRACTCE20	6.13E+12	0.005773	0.002843
19	Council district	5.99E+12	0.005644	0.002780
20	Census tract	5.00E+12	0.004706	0.002318

All errors are proportional, no conflict among Root Mean Square Error (RMSE), Mean Square Error (MSE) and Mean Absolute Error (MAE). Otherwise, we will prefer to rely on RMSE, since it categorically penalizes larger deviations which is characteristic with most of the large datasets, as well as outliers. Based on numbers, Stacked Ensemble dominates the leaderboard compared to GBM, where (cross-validation, k = 3) is number 1, as shown in Table 2. The reason Stacked Ensemble performed better could be the high standard deviation nature of data, especially the label, Total Value.

To better judge the RMSE performance, we look at the R^2 for both training and validation data. As shown in Table 3, they both perform very accurately, 0.98 and 0.96 respectively. AIC seems to be very high, as expected, since Land Value and Sales Price's standard deviation are very significant, as a potential reason, they can dominate the important factors and leave other attributes to fulfill the rest.

As seen in Table 4, Land Value and Neighborhood explain 77% of Total Value, whereas the other 55 attributes make up the left-over, 23%. In other words, all the information that is being collected is implicitly excluded to have a say on Total Value, a.k.a. assessment value. As suggested previously, making some selected attributes a part of the equation (and eliminating the rest accordingly) will decrease the AIC, as well as serve the check and balance of the valuing system. For instance, introducing the Sale Prince (the last sold, to be adjusted each year) as a solid real number, rather than speculations, as well as an incremental Charge, one-time fee, for added pool, fireplace, an extra floor, additional room, garage, etc. might help to fine-tune the assessment valuation which is currently biased to Land Value and Neighborhood dominantly.

5. Implications

Local governments should revisit why they need money after they evaluate the needs, they need to collect it per need, so stakeholders can feel like a part of it. When they do that, they should remember that property taxes do not have to dominate the revenue, they may want to remember other options, like Corporate Income Tax, that no level is leveraging properly, including federal and state. Lastly, they should also reevaluate the assessment dynamics, where volatility should be predictable, unlike today's models. The tone of what is being done is mostly compartmentalized by overdependence and overemphasize, which are unfavorable per any management science school of thought:

- Overdependency on property taxing with local revenue: Property tax cannot be a last resort by its nature since it affects seller-buyer dynamics and markets. In case there is a need, one-time fees within charges and/or state transfers may need to compensate the ultimate need accordingly. Alternatively, underrepresented 'Corporate Income Tax' might also be made scrutiny. Since it is not a significant part of any level, federal, state, and local, local jurisdictions may develop a project to leverage it partly.
- Overdependency on assessment value with property taxing: Adding some tangible elements (e.g., size, additions) into property tax calculation may favor a less volatile structure or more predictable volatility and fence the implicit misperception about endlessly adjustable property taxes with no boundaries. Raw data allows us to utilize endless possibilities, such as added pool, fireplace, extra floor, additional room, and garage, in this regard, with no extra effort.
- Overemphasis on needs: As individuals, homemakers, and nearly all institutions practice, investments should be made per budget, in other words, budget cannot follow investments or any impulse need. After all, most needs look like they are dominated by schools. Ironically, bad-performing school districts do not necessarily lead to adjusted property taxes, like they also do not fall with falling property prices. This one-sided relationship would make things even more complicated for both parties, homeowners in the short term and local governments in the long term.

Lack of uniformity, subjectivity, bias, and outdated assessments due to administrative burden would create shortcuts with no benefits for anyone. Personal judgments and interpretations of assessors lead to inconsistencies. To help improve the accuracy and universality of assessments, local governments should work on a balanced formula with variables and fixed fees, that each stakeholder can easily understand. Creating clear guidelines and standards, including the hearing process, would increase confidence and help to serve to figure out a simple answer to a simple question, how and why the tax is to be collected, rather than tying with an assessment value that even local governments cannot understand it entirely, in a homogenous way.

Real-estate development is more concerned with sustainability, which is fed by long-term stability. Today's property development has rivalry with two heavy weights; record interest rates and sky rocketing property tax rates. As shown in Figures 10 and 11, the new home months supply is far from making an impact on price adjustments, which is unfavorable for home buyers (EBP Research, 2023).

With an example, a $500K-house in high property tax cities, might have a typical monthly payment of $3K ($2K approximate interest in average, $1K is the house itself) bank and $1K property tax per month, for a 30-year mortgage with 20% down payment. With two third interest, property developers are only generating $1K per month, only 25% of total dollar value; on top of this, for only a 25% profit on average, it takes the risks for the inflation of fundamentals, constructions steel, all appliances. This is unfavorable for property developers and creates a chicken-egg situation, where it makes it only worse. As a business, they can always choose to invest for another business line, however, this is another area that governments need to be more cautious, since at the end of the day, people need to live somewhere, and very low housing supply would have social consequences.

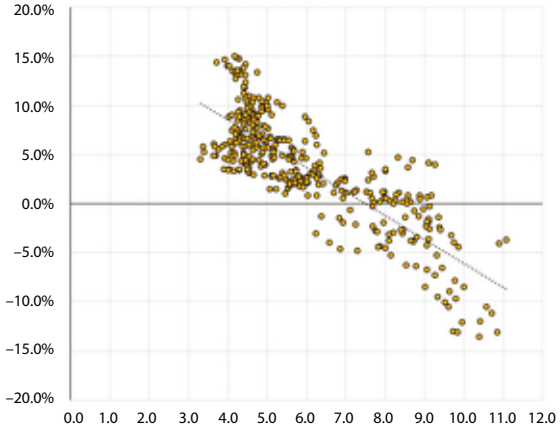

Figure 10. Total months supply vs future home price growth (EBP Research, 2023)

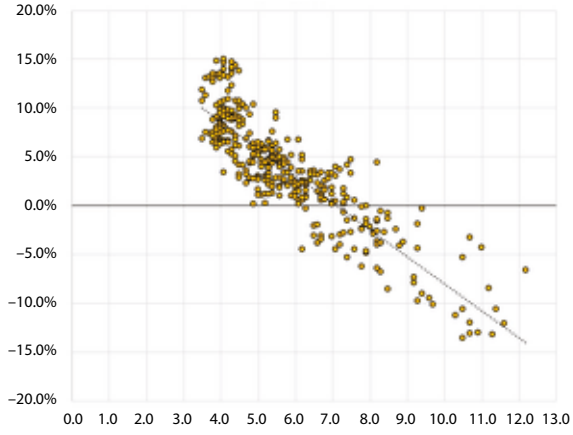

Figure 11. New months supply vs future home price growth (EBP Research, 2023)

Conclusions

Assessment-based property tax increases unmatched expenses in bubble economies. There is a substitution problem in rapid falls, the tendency not to drop assessments arises, it gives way to black holes, and opens the door to ghost cities. Therefore, maintenance should be based on wage growth environments, not even directly attached to inflation or interest rates. Just like all companies and people, municipalities should plan accordingly. Moreover, charging tax on an assessment value that has not been sold is fundamentally against the logic of taxation. The first thing to do is to diversify the tax distribution and balance their weights.

The second is to save property tax, which is our main subject, from assessment-based formulas, by preserving the budget. In a world where the goal is not to reduce the budget but to increase predictable volatility, a typical model may include three components with brackets:

1. Assessment/Market value but based on the last sold, to be increased each year by the average wage growth ideally (Variable with %): Two brackets that will range from 1% to 1.5% (for homes over $million) on the last sold price.
2. Utilization tax (Variable with %): One additional rate item with three brackets, which will vary amongst 0.3%-0.4%-0.5% per child, according to the school (varying from Level 2, 3 to 4 respectively, where Level 4 is the highest, and there is utilization tax for Level 1 schools) rankings, and
3. Property charge (Fixed cost with amount): One one-time fee (to be increased by the average wage growth ideally) for investment/development, such as added pool, fireplace, extra floor, additional room, garage, etc. Raw data showed us that all those attributes are being collected yearly and they can be leveraged with no extra cost. Home maintenance is historically compartmentalized as 2% of the home value each year, where some changes may categorically fall into an area that is subject to be taxed. Only a 10% cut on average would yield a mean of 0.2% extra annually.

With two different interpretations:

– A family with 3 children living in an over million dollars house, Level 4 school district, would need to pay 1.5% for number 1, another 1.5% for number 2, and typically some fixed fees (maybe rounded as 0.2%) for home development (e.g., extra garage) that would end up with 3.2% as property tax.
– A family with 2 children, living in a less-than-million-dollar house, in Level 3 district, would need to pay 1% for number 1, another 0.8% for number 2 and may have a pass for home development that year, and may end up with only 1.8% as property tax.

The problem with today's tax valuing systems does not allow citizens to make arrangements in any possible way. Moreover, they may keep paying the same high taxes even if they cannot leverage any tangible benefit (e.g., the schools do not perform well enough) anymore until they cannot pay. A better valuing system would serve checks and balances, would yield not necessarily less revenue, but be more predictable for both parties, local governments, and homeowners. Knowing that sustainability hypothetically threatens long-term objectives, to not jeopardize the short-term gains, it would be fair to note that local politicians would take it out of sight, as they can. From this perspective, this issue might be a concern for federal governments. In other words, it deserves their attention more and to prevent future anomalies, they might be the one who need to regulate more.

Limitations

A model proposal that can replace an assessment value-dominated property rating system can only be developed using raw data, which is a very rare occasion. There are two common scenarios, jurisdictions either share a summary table, which is a pivoted version of the raw data, or promote a property address search service, which only yields your property's attributes or another, but it is one record per search and no raw data whatsoever.

What makes the City of Buffalo special is twofold. First, its property tax share on local revenue is aligned with the United States national average. Second, the raw data is full of all records, all properties (93.7K houses) in the city, and all possible attributes, 88 columns. The limitation is that it looks like an exception, therefore it does not give a public chance to validate the study with other cities.

Future directions

A typical research and practice agenda comes twofold.

First, mimicking our research with other cities, to observe similarities and differences can be considered as an option, as well as piloting our findings in the field, concerning assessment value practices can also make a natural addition.

Second, adding a vertical (a new research, spin-off) dimension can be considered a new path. Under-utilized property taxes are also the taxes that are being over-represented per state and local revenues, like very well-utilized taxes, with only one difference, with no utilization efficiency. Some states/counties continuously overemphasize property taxes within the local revenues with not necessarily a tangible benefit, like school performance. This may jeopardize the future of the county since seller-buyer dynamics may turn to a dead end. Two separate problems can be scrutinized, how to prevent over-representation (e.g., Corporate Income Tax' contribution seems to be very small, yes, it deserves attention, however, this is an overall issue, and it is more related for federal revenue researchers) and how to spend (which is more important, where does the existing money go) efficiently. To raise a solid question, if a county collects 3%, which is one of the highest bracket tax ratios, why and how they may have very underperforming schools would be a significantly valid point to scrutinize.

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Author contributions

I, Emre Ozmen, am the sole author.

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The research conducted for this paper was carried out with utmost objectivity and integrity, adhering to the highest ethical standards. There are no affiliations, financial arrangements, or other relationships that could be perceived as a potential conflict of interest.

Furthermore, I confirm that this research has been performed in accordance with the guidelines and regulations set forth by the relevant ethical committees or institutional review boards, if applicable. The data used in this study were obtained from legitimate sources and comply with the necessary privacy and confidentiality regulations.

I assure you that the information presented in this manuscript is accurate to the best of my knowledge. Any errors or omissions are unintentional, and I am committed to rectifying them promptly, should they come to my attention.

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Appendix

Table A1. Property tax revenue, share of state and local (City of Buffalo, 2020)

Column name	Description	Type
# of baths	The number of baths in a dwelling (only applicable to residential properties)	Number
# of beds	The number of beds in a dwelling (only applicable to residential properties)	Number
# of fireplaces	The number of fireplaces in a dwelling (only applicable to residential properties)	Number
# of kitchens	The number of kitchens in a dwelling (only applicable to residential properties)	Number
# of stories	The area of the first floor in a dwelling (only applicable to residential properties)	Number
Acres	Acreage of a parcel	Number
Add area	Additional area	Number
Address	The full street address where the parcel of real property is located	Plain text
Attic area	The area of the attic	Number
Basement type	The type of basement on the property (only applicable to residential properties)	Plain text
Bill number	The bill number associated with the parcel	Plain text
BOECKH	The model number associated to the Boeckh Building Valuation Manual.	Plain text
Building style code	Building style code	Number
Building style description	Style of building	Plain text
Census block	The 2010 census block where a parcel of real property is located	Plain text
Census block group	The 2010 census block group where a parcel of real property is located	Plain text
Census tract	The 2010 census tract where a parcel of real property is located	Plain text
Central air	The percentage of the gross floor area which is air conditioned	Plain text
CONSINCVAL	CONSINC value	Number
Construction grade	The code associated with the overall construction grade of the parcel	Plain text
Construction grade description	A description of the overall construction grade of the parcel	Plain text
Construction quality code	The code associated with the overall construction quality of the parcel	Number
Construction quality description	A description of overall construction quality of the parcel	Plain text
Council district	The council district where a parcel of real property is located	Plain text
Council district abbreviation	An abbreviation of the council district associated with the parcel	Plain text
Deed book	The book number given to the last deed recorded with the Erie County Clerk's office	Number
Deed date	The date the deed was filed with the Erie County Clerk's office	Date & time
Deed page	The page number given to the last deed recorded with the Erie County Clerk's office	Number
Deed type code	The code associated with the deed type of the parcel	Plain text
Deed type description	A description of the type of deed associated with the parcel	Plain text
Depth	The depth of the property (in feet)	Number
Description 1	Description 1	Plain text
Description 2	Description 2	Plain text
Description 3	Description 3	Plain text
Exterior wall code	The code associated with the material of the property's exterior walls	Number
Exterior wall description	A description of the materials of the property's exterior walls	Plain text
First story area	The area of the first story	Number
Front	The width of the front of property (in feet)	Number
Fuel type	Fuel type	Number
GEOID20_block	The geographic identifier assigned to the 2020 census block where the parcel is located	Plain text
GEOID20_blockgroup	The geographic identifier assigned to the 2020 census block group where the parcel is located	Plain text
GEOID20_tract	The geographic identifier assigned to the 2020 census tract where the parcel is located	Plain text
Heat type	The type of heating system in the building (only applicable to residential properties)	Plain text
Heat type description	A description of the heat type of the property	Plain text
Homestead code	The code used to designate the homestead class of the property	Plain text

End of Table A1

Column name	Description	Type
House number	The assessed street address number associated with a parcel of real property	Plain text
Land value	The assessed value of the land	Number
Latitude	The latitude of the location of the parcel of real property	Number
Location	The location of the parcel of real property	Point
Longitude	The longitude of the location of the parcel of real property	Number
Mail country	The country of the owner's mailing address	Plain text
Mail Zipcode	The 5 digit zip code of the mailing address of the property owner	Plain text
Mail Zipcode extension	The 4 digit zip code extension of the mailing address of the property owner	Plain text
Mail1	The mailing address of the property owner	Plain text
Mail2	The mailing address of the property owner	Plain text
Mail3	The mailing address of the property owner	Plain text
Mail4	The mailing address of the property owner	Plain text
Neighborhood	The neighborhood where a parcel of real property is located	Plain text
Number of units	The number of units	Number
Overall condition	A grade of the condition of the property	Plain text
Overall condition description	The general condition of the building(s) on the site	Plain text
Owner1	The owner of a parcel of real property	Plain text
Owner2	The owner of a parcel of real property	Plain text
Police district	The police district where a parcel of real property is located	Plain text
Previous number	The previous owner of a parcel of real property	Plain text
Previous property class	The parcel of real property's property class code on the previous assessment roll	Plain text
Print key	A secondary format for SBL, a unique geographic identifier for all parcels, stands for Section-Block-Lot number	Plain text
Prop class description	A description of the primary use of each parcel of real property on the assessment roll	Plain text
Property class code	The property class code for the parcel of real property	Plain text
Roll	A code to indicate the portion the portion of the assessment roll. For example, roll section 1 is taxable. Roll section 8 is tax-exempt	Plain text
Sale price	The price that the parcel of real property was last sold for	Number
SBL	A unique geographic identifier for all parcels, stands for Section-Block-Lot number. It is where the parcel is located on the County tax maps	Plain text
Second story area	The area of the second story	Number
Special district code	The code of special districts associated with the parcel	Plain text
Story Height	The average story height in feet measured from the surface of one floor to the surface of the next floor or roof	Number
Street	The assessed street name where the parcel of real property is located	Plain text
SWIS	The 6 character numeric code that uniquely identifies each county, city, town, and village within the State of New York	Plain text
Tax district	The last two digits represent the tax district where the parcel of real property is located	Plain text
Total living area	The amount of living space (in square feet)	Number
Total value	Assessed value of the parcel	Number
TRACTCE20	The six-digit 2020 census tract of the parcel	Plain text
Used as code	The alphanumeric code, which categorizes the USED-AS CODE dominant use of the site	Plain text
Wall A	Used to record the exterior wall material, which most closely reflects the structure. There are three exterior wall categories available: A, B, and C	Plain text
Wall B	Used to record the exterior wall material, which most closely reflects the structure. There are three exterior wall categories available: A, B, and C	Plain text
Wall C	Used to record the exterior wall material, which most closely reflects the structure. There are three exterior wall categories available: A, B, and C	Plain text
Year built	The year the primary building on the parcel was built	Number
Zipcode	The 5-digit zip code associated with the parcel of real property	Plain text
Zipcode extension	The 4-digit zip code extension used after the 5-digit zip code to refer to a more specific postal delivery area	Plain text