

Accuracy Evaluation of Low-Cost and Professional UAS Orthomosaics for 2D/3D Urban Cadastre Mapping

Autores:

Allan Gomes | IFSC | allan.gomes@ifsc.edu.br

Renato Z. Araujo | IFSC | renato.araujo@ifsc.edu.br

Francisco H. de Oliveira | UDESC | francisco.oliveira@udesc.br

CONTEXTUALIZATION

UAS for 3D Data Acquisition

- UAS enable agile, cost-effective 3D data collection (point clouds, DSM, orthomosaics).
- Modern systems store GNSS and IMU information directly in the image metadata.

Georeferencing methods

- Direct Georeferencing: no ground control points required.
- Indirect Georeferencing: requires ground control points (GCPs).

Accuracy depends on the GNSS positioning method used (SPP, RTK, PPK, etc.).

Accuracy Validation

- Based on check points and RMS analysis, following national standards (PEC Decree 89.817/1984, INCRA georeferencing standards).

Challenge

Can low-cost UAS deliver accuracy comparable to professional systems for cadastral mapping?

METHODOLOGY

Study Area

- IFSC Campus, Florianópolis (~5 ha)
- 38 photo-identifiable points (11 control-GCPs, 27 check-CPs)

Flight Missions

- Image Overlap: 70% front / 70% side
- Camera direction -90° (no oblique)
- Altitude: 70 m
- Flight speed: 4 m/s

Processing and Accuracy Assessment

- Software: Agisoft Metashape
 - Mini 3: Indirect Georeferencing
 - Matrice + P1: Direct Georeferencing

Accuracy Analysis

- Metashape: RMS (internal adjustment)
- GeoPEC: RMS + compliance with cartographic standards

Standards

- PEC – Brazilian Cartographic Accuracy Standard (Decree 89.817/1984)
- INCRA – Georeferencing Norms for Rural Properties



Figure 1. UAS DJI Matrice 350 + P1 and DJI Mini 3

Table 1. UAS Specification

Specification	DJI Mini 3	DJI Matrice 350 RTK + P1
Aircraft type - DJI	Consumer	Professional
Dimensions (folded)	148 × 90 × 62 mm	430 × 420 × 430 mm
Takeoff weight	~249 g	~7.27 kg (with P1 camera)
Flight endurance	~38 min	~55 min
Maximum flight distance	~18 km	~20 km
Camera focal length	6.7 mm	35 mm (Zenmuse P1)
Sensor size	1/1.3" CMOS	Full-frame 35 mm CMOS
Camera resolution	12 MP	45 MP
GNSS method capability	SPP	SPP, RTK, PPK, and Network RTK
Estimated price (2025, BR)	~R\$ 4,500–6,000	~R\$ 140,000–180,000 (with P1 camera)

RESULTS

Table 2. Processing time, output size and GSD for each UAS Metashape workflow (Alignment, Depth Maps, Point Cloud, DSM and Orthomosaic)

	Matrice 350 + P1	Mini 3
Time Spend	4 h 47 min 36 s	32 min 7 s
Size	27.81 GB	10.39 GB
GSD (orthomosaic)	8.40 mm/pix	2.34 cm/pix

Surface Models

Mini 3 DSM → noticeable noise, roof irregularities, vegetation distortion. Require more manual corrections

Matrice + P1 DSM → smoother, sharper building outlines, better elevation consistency.

Both flights captured at -90° , but adding oblique imagery (45°) could improve accuracy.

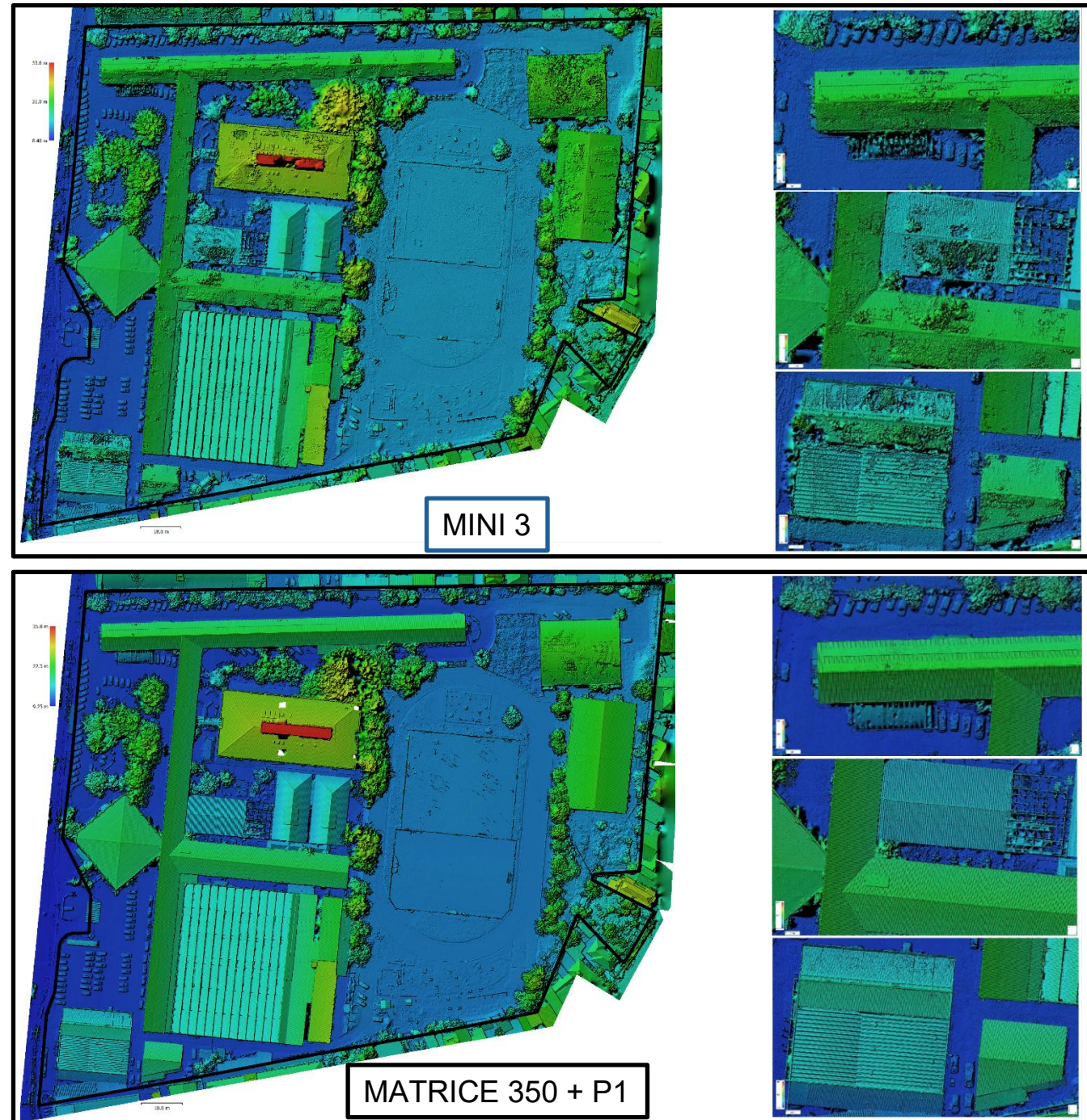


Figure 3. DSM generated with Mini 3 (top) and Matrice 350 + P1 (bottom).

RESULTS

Orthomosaic

Mini 3 → noticeable noise
but acceptable.

Matrice + P1 → smoother,
sharper building outlines.

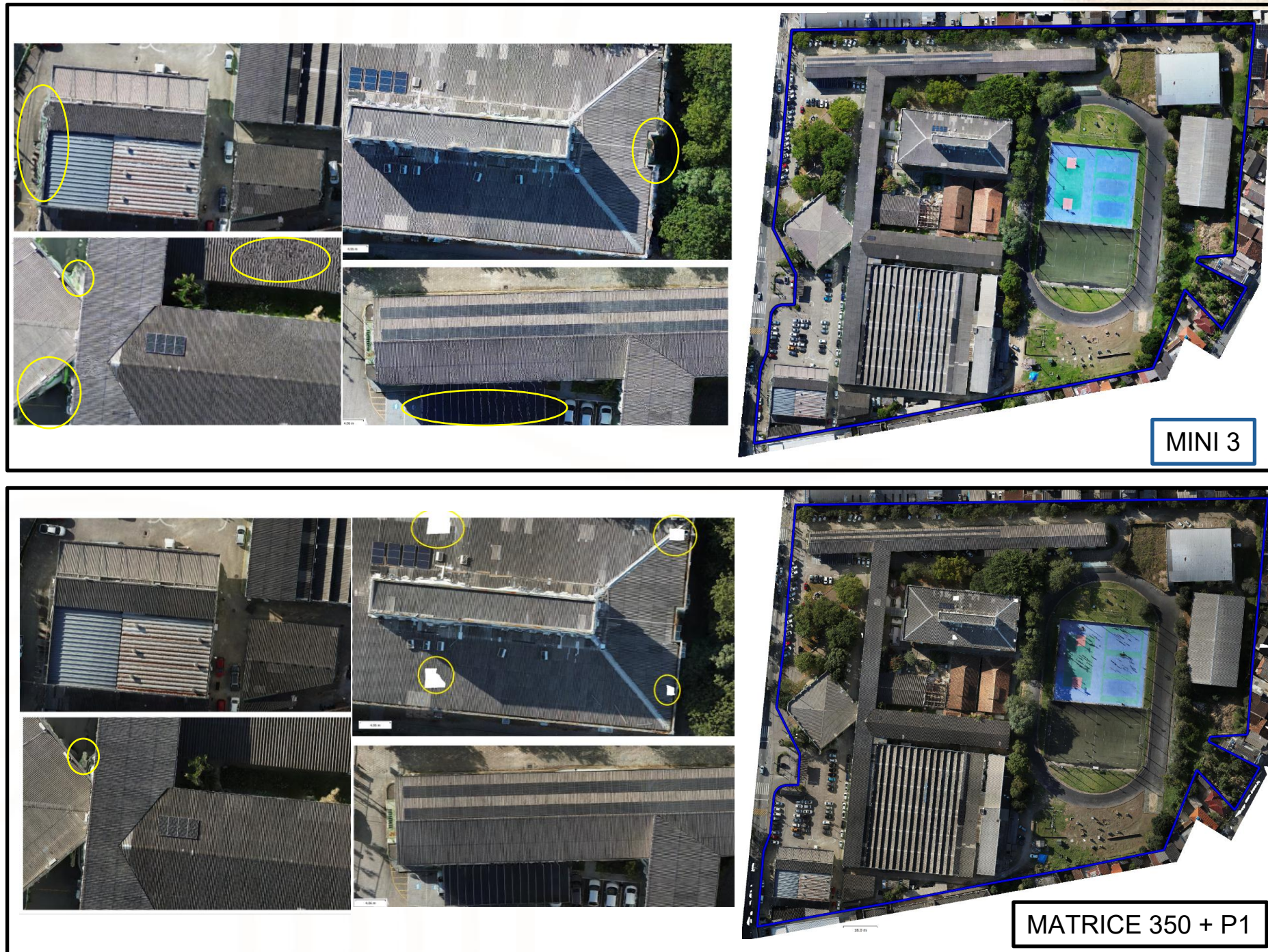


Figure 5. Orthomosaic generated with Mini 3 (top) and Matrice 350 + P1 (bottom).

RESULTS

Accuracy assessment performed in GeoPEC software
Both datasets meet PEC Class A (1:1000) and INCRA standards.

Table 3. RMS values from GeoPEC

UAS	Point type	Number	GEOPEC RMS (cm)				
			East	North	Alt.	XY	Total
Mini 3	Check	27	3.77	3.17	9.86	4.93	11.02
Matrice 350	Check	27	1.36	1.84	3.39	2.30	4.09

Acurácia Posicional (Decreto 89.817 / ET-CQDG) - Planimetria

Escala de teste: 1/1000 Área de Estudo: 5 Unidades: ha Nº Pts Total: 27 Nº Pts Excluídos do cálculo: 0

Distribuição Espacial Teste de Normalidade Tendência Decreto 89.817 / ET-CQDG Acurácia (Resumo Resultados)

Padrões do Decreto 89.817/ET-CQDG:

Classe	ET-CQDG	PEC (mm)	EP (mm)	PEC (m)	EP (m)
A	A	0,280	0,170	0,28	0,17
B	B	0,500	0,300	0,5	0,3
C	C	0,800	0,500	0,8	0,5
D	D	1,000	0,600	1	0,6

Classificação do Decreto 89.817 / ET-CQDG:

Classe	ET-CQDG	%d(E) <= PEC	%d(N) <= PEC	%d(abs) <= PEC	RMS <= EP	Resultado
A	A	100,000	100,000	100,000	Passou	Aprovado
B	B	100,000	100,000	100,000	Passou	Aprovado
C	C	100,000	100,000	100,000	Passou	Aprovado

INCRA - Manual técnico de Georreferenciamento 2ª edição - 2022

Escala de teste: 1/1000 Nº Pts Total: 27 Nº Pts Excluídos do cálculo: 0

INCRA Acurácia (Resumo Resultados)

Classificação
Escala: 1 / 1000
Decreto / ET-CQDG: Classe A

Tipo de Limite
Artificial (0,5 m): **Atende**
Natural (3,0 m): **Atende**
Inacessível (7,5 m): **Atende**

ACURÁCIA
O produto ATENDE as normativas do INCRA

Metodologia: Manual Técnico de Georreferenciamento - 2ª edição - 2022

Figure 6. Results from GeoPec evaluation

Table 3. RMS values from Metashape

UAS	Point type	Number	Metashape RMS (cm)				
			East	North	Alt.	XY	Total
Mini 3	Control	11	1.78	2.10	1.73	2.76	3.25
	Check	27	4.05	3.54	8.56	5.38	10.11
Matrice 350	Check	27	1.43	1.89	3.16	2.37	3.95

Table 4. Positional discrepancies (Δ) of check points measured in the orthomosaics.

ID	Mini 3			Matrice 350 + P1		
	Δ East (m)	Δ North (m)	Δ Alt. (m)	Δ East (m)	Δ North (m)	Δ Alt. (m)
1	0,02	0,06	-0,03	0,01	0,00	-0,02
2	0,01	0,01	0,03	-0,01	-0,04	-0,01
3	0,03	0,04	0,05	0,02	0,00	-0,02
4	0,05	0,03	0,01	0,02	-0,01	-0,04
5	0,07	0,00	0,02	0,02	-0,01	-0,02
6	0,05	0,03	0,06	0,02	0,01	-0,02
7	0,03	-0,04	-0,09	0,02	0,02	-0,04
8	-0,06	-0,06	-0,30	-0,01	0,02	-0,09
9	-0,05	-0,03	-0,01	0,00	0,00	-0,03
10	-0,05	-0,02	-0,05	-0,02	0,01	-0,05
11	0,01	0,03	0,07	0,01	0,02	-0,02
12	-0,01	0,01	0,05	-0,02	0,03	-0,04
13	-0,01	-0,02	0,06	0,00	0,03	0,00
14	0,00	-0,01	0,11	-0,01	0,03	-0,01
15	-0,06	-0,03	0,09	-0,02	-0,02	0,00
16	-0,02	0,01	0,11	-0,01	-0,01	-0,02
17	-0,05	0,00	0,06	0,00	0,00	-0,04
18	-0,03	0,01	0,04	-0,01	-0,02	-0,01
19	-0,04	0,02	0,01	0,00	-0,03	-0,03
20	-0,05	0,04	0,10	-0,03	-0,02	-0,02
21	-0,03	0,04	-0,09	0,01	-0,03	-0,05
22	-0,03	0,05	-0,13	0,02	-0,01	-0,03
23	-0,01	0,02	0,25	0,00	0,00	-0,02
24	0,00	0,01	0,08	0,02	-0,01	-0,02
25	-0,06	0,04	0,02	-0,02	0,00	-0,02
26	-0,01	0,05	-0,01	0,01	-0,01	-0,05
27	0,02	0,00	-0,03	0,00	-0,01	-0,05

CONCLUSIONS

Matrice + P1 achieved superior results (GSD = 0.84 cm; RMS $\approx$ 4 cm), producing smoother DSMs and sharper building outlines — ideal for 3D modeling and volumetric analysis.

Mini 3, despite higher RMS ($\approx$ 11 cm) and noisier DSMs, met PEC Class A (1:1000) standards when processed with dense GCPs.

Mini 3 advantages: low cost, portability, no flight authorization required (<250 g) — valuable for small municipalities with limited budgets.

Drawbacks: greater manual correction and more post-processing effort required.

Both systems meet the national accuracy standards (PEC and INCRA), confirming the feasibility of low-cost UAS for municipal cadastral applications when properly controlled.

Tests used only nadir flights (90°); including oblique (45°) or cross-flight patterns could improve model accuracy.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of FIG, IFSC, IBGE, and all collaborators involved in this research



execução



patrocinadores



MINISTÉRIO DA
GESTÃO E DA INOVAÇÃO
EM SERVIÇOS PÚBLICOS

