

Digital Construction Implementation in the Era of Industrial Revolution 4.0 Using Augmented Reality Technology to Determine Building Coordinates

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(Received: 13th September 2024 ; Revised: 9th December 2024 ; Accepted: 27th December 2024)

Abstract: The Industry revolution 4.0 has become a prominent topic of discussion, emphasizing the need to harness digital technology to enhance various aspects of human work, including the construction industry. In the field of construction, Building Information Modeling (BIM) has been widely adopted as a guiding framework for construction processes. Additionally, Augmented Reality (AR) technology has emerged as a powerful tool for bringing 3D models into the physical world. This research employs a qualitative approach, utilizing 3D design data of Pile Caps in the construction of the IKN Minister's Residence and Solo - Yogyakarta Toll Road Office. A total of 74 and 68 coordinate points were extracted from each design to analyze the discrepancies resulting from the implementation of AR technology. The findings reveal that both designs exhibited a margin of error of 0.6148648649 % for the IKN Minister's Residence and 0.6102941177 % for the Solo - Yogyakarta Toll Road Office, both of which fall below the 1% threshold for maximum allowable error.

Keyword : *Surveying, Augmented Reality, Building Information Modeling.*

1. Introduction

The indicators of the Industry 4.0 revolution are gradually finding their way into diverse sectors [1]. Within the construction domain, Building Information Modeling (BIM) stands out as a widely recognized information technology. BIM plays a pivotal role in supporting various aspects of project management, encompassing design planning, scheduling, cost estimation, and the dissemination of critical project information. The incorporation of BIM has now become a prerequisite for enhancing sustainability and productivity in the construction industry [2]. Augmented Reality (AR), on the other hand, possesses the capability to seamlessly integrate virtual data generated by computers into the real-world environment [3].

2. Literature Study

In The Fourth Industrial Revolution, Klaus delineates four distinct stages of revolution that have shaped the world. These stages are as follows: 1) The First Industrial Revolution, occurring in the 18th century with the invention of the steam engine, enabling mass production of goods. 2) The Second Industrial Revolution, taking place in the 19th to 20th centuries, characterized by the widespread use of electricity that significantly lowered production costs. 3) The Third Industrial Revolution, emerging in the 1970s through computerization. 4) The Fourth Industrial Revolution

itself, unfolding around the 2010s, driven by the integration of artificial intelligence and the Internet of Things as the backbone of human-machine connectivity and mobility. The Fourth Industrial Revolution fundamentally alters how humans think, live, and interact with one another. This era disrupts various human activities across diverse fields, extending beyond technology into economics, social dynamics and construction [4]. In the construction industry, the determination of coordinates necessitates the practice of surveying. Surveying can be defined as the science of establishing the position, in three dimensions, of natural and/or artificial objects above or below the Earth's surface. Measurement results are typically represented in contour maps, plan sketches, and digital formats as digital ground models [5]. One of the digital tools used to support construction processes is Building Information Modeling (BIM). BIM is an information technology that enables the study of buildings without the need for physical construction. BIM has evolved significantly in developed countries, while many construction companies in Indonesia still rely on conventional software such as AutoCAD for design, SAP for structural analysis, MS Excel for volume and cost calculations, and MS Project for scheduling [6]. With the advancement of technology and the prevalence of sophisticated smartphones, a revolution is needed to simplify coordinate determination for users. Augmented Reality (AR) is a technology that integrates computer-generated models into the real world. AR has been in existence for about 50 years but was coined as a term in 1992. Despite its long history, AR has not been widely adopted due to limitations in available equipment and the complexity of implementation at the time [7].

3. Methodology

This research employs a qualitative methodology due to the inherent diversity of values associated with each object of study. Additionally, it aligns with the qualitative approach's recognition that reality is dual, complex, dynamic, and that the truth of reality is dynamic [8]. The study focuses on two buildings selected for testing purposes: the IKN Residence and the Solo-Yogyakarta Toll Office. These objects were derived from the 3D BIM Developer projection, scaled at a ratio of 1:100. Subsequently, the objects were processed to obtain the coordinate points of the Pile Caps of the buildings, which serve as reference models, as presented in Tables 1 and 2. Once the coordinate points were obtained, they were integrated into an Augmented Reality application to determine the error values.

Errors within equations (functions) or the omission of various important variables can result in specific error levels. The most effective way to create a robust model is by studying the magnitude of differences, such as those between modeling results and reality. These differences should follow a normal distribution, with no significant deviations [9].

Table 1. Reference Values along the (X,Y) Axis for the IKN Minister's Residence Building

Column	Testing Models	Reference Value (mm)	
		x	y
A	A1	0	0
	A2	0	240
	A3	240	240
	A4	240	0
B	B1	-250	440
	B2	-250	680
	B3	0	680
	B4	440	0
C	C1	-250	1050
	C2	-250	1200
	C3	0	1200
	C4	0	1050

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Column	Testing Models	Reference Value (mm)	
		x	y
D	D1	410	660
	D2	410	900
	D3	650	900
	D4	650	660
E	E1	410	410
	E2	410	640
	E3	650	640
	E4	650	410
F	F1	340	0
	F2	340	240
	F3	380	240
	F4	580	0
G	G1	790	110
	G2	790	350
	G3	1030	350
	G4	1030	110
H	H1	790	410
	H2	790	640
	H3	1030	640
	H4	1030	410
I	I1	790	660
	I2	790	900
	I3	1030	900
	I4	1030	660
J	J1	1480	660
	J2	1480	900
	J3	1730	900
	J4	1730	660
K	K1	1480	410
	K2	1480	640
	K3	1030	640
	K4	1730	410
L	L1	1480	111
	L2	1480	350
	L3	1730	350
	L4	1730	110
M	M1	1900	112
	M2	1900	350
	M3	2130	350
	M4	2130	110
N	N1	1900	410
	N2	1900	640
	N3	2130	350
	N4	2130	410
O	O1	1900	660
	O2	1900	900
	O3	2130	900
	O4	2130	660

Column	Testing Models	Reference Value (mm)	
		x	y
P	P1	410	1060
	P2	410	2030
	P3	780	2030
	P4	780	1375
	P5	1420	1375
	P6	1420	1875
	P7	2060	1875
	P8	2060	1290
	P9	2130	1290
	P10	2130	1210
	P11	2370	1210
	P12	2370	930
	P13	1730	930
	P14	410	1060

Table 2. Reference Values along the (X,Y) Axis for the Solo – Jogja Toll Road Office

Column	Testing Models	Reference Value	
		x	y
1	A	0	0
	B	0	130
	C	130	130
	D	130	0
4	A	-592	107
	B	-592	212
	C	-462	212
	D	-462	107
5	A	-592	478
	B	-592	628
	C	-462	628
	D	-462	478
8	A	-602	1395
	B	-602	1525
	C	-472	1525
	D	-472	1395
9	A	-44	1395
	B	-44	1525
	C	86	1525
	D	86	1395
10	A	-44	1887
	B	-44	2017
	C	86	2017
	D	86	1887
11	A	-340	2283
	B	-340	2413
	C	-210	2413
	D	-210	2283
28	A	1655	2283
	B	1655	2413
	C	1785	2413
	D	1785	2283
39	A	3708	2283
	B	3708	2433
	C	3858	2433
	D	3858	2283

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Column	Testing Models	Reference Value	
		x	y
42	A	3708	1182
	B	3708	1312
	C	3858	1312
	D	3858	1182
44	A	373	195
	B	373	326
	C	385	326
	D	385	195
47	A	2332	181
	B	2332	341
	C	2492	341
	D	2492	181
48	A	1656	295
	B	1656	425
	C	1786	425
	D	1786	295
49	A	1158	165
	B	1158	295
	C	1288	295
	D	1288	165
50	A	1158	0
	B	1158	130
	C	1288	130
	D	1288	0
51	A	763	0
	B	763	130
	C	893	130
	D	893	0
52	A	516	0
	B	516	130
	C	646	130
	D	646	0

4. Result and Discussion

In this research, reference values were obtained through manual calculations of the (X,Y) coordinates of the building's Pile Caps, scaled at 1:100 and measured in millimeters. The measured values result from the alignment of the building as displayed in Augmented Reality (AR). Error is defined as the difference between manual coordinates and the building's coordinates obtained through AR visualization. Error as a percentage (%), is calculated by multiplying the error value by 100%.

4.1. Model 3D Pile Cap

The Pile Cap object used is the original model from the Building Information Modeling file at a scale of 1: 100.

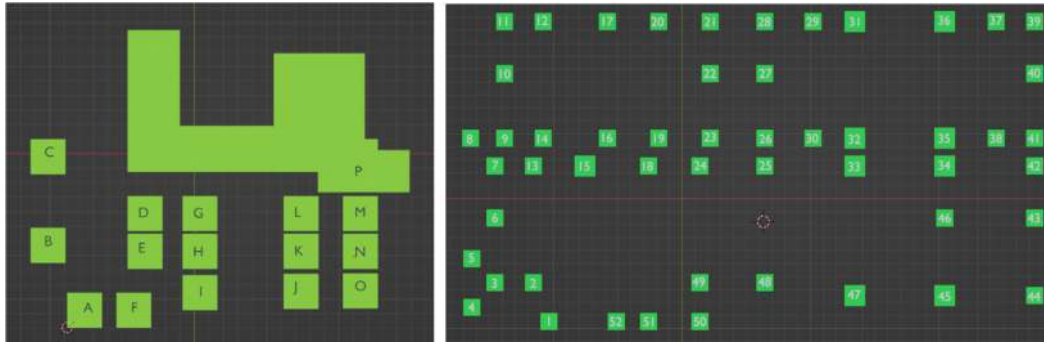


Fig. 1. IKN Minister's Residence Building and Solo-Jogja Toll Road Office Pile Cap.

4.2. Manual Testing Model Measurement

Reference Measurement for Augmented Reality Calibration in this Study Includes:

1. Prepare millimeter paper.
2. Attach the marker paper to the millimeter paper.
3. Establish coordinates along the X and Y axes.
4. Create column lines using the coordinates as per the test model.



Fig. 2. Manual Calculating of IKN Minister's Residence Building and Solo-Jogja Toll Road Office.

4.3. Test Model Measurement Using Augmented Reality (AR)

In this study, test model measurements were conducted using the ARCons application. The measurement process involved the following steps:

1. Install the ARCons Augmented Reality application.
2. Press the Scan button.
3. Point the camera towards the marker (if detected, the visual representation of the Pile Cap building will appear).
4. Create reference points using a pencil or marker in accordance with the model generated by AR.

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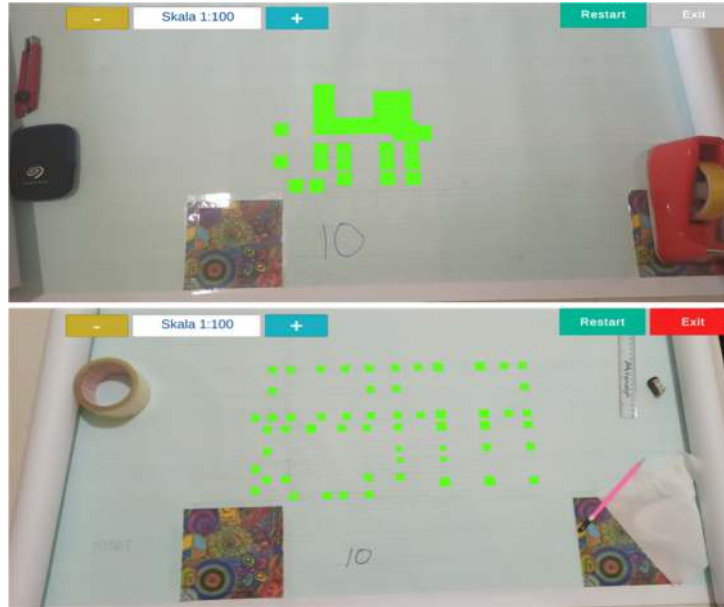


Fig. 3. AR Calculating of IKN Minister's Residence Building and Solo-Jogja Toll Road Office.

4.4. Error Measurement Results

Error measurements were carried out on 2 objects and each test was carried out 6 times. The results of these measurements can be seen in tables 3 and 4 below:

Table 3. IKN Minister's House error testing

Column	Testing Model	Value Reference (mm)		Testing 1 (10th minute)		Testing 2 (20th minute)		Testing 3 (30th minute)		Testing 4 (40th minute)		Testing 5 (50th minute)		Testing 6 (60th minute)	
		x	y	x	y	x	y	x	y	x	y	x	y	x	y
A	A1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A2	0	240	1	245	1	245	1	240	1	240	1	240	1	241
	A3	240	240	239	243	250	243	240	240	240	241	240	240	240	240
	A4	240	0	240	1	251	1	240	0	240	1	240	0	240	0
B	B1	-250	440	-251	441	-255	441	-250	441	-251	441	-250	441	-249	442
	B2	-250	680	-251	681	-255	681	-250	681	-251	681	-250	681	-251	681
	B3	0	680	-1	691	-5	691	0	681	0	681	0	681	0	682
	B4	440	0	450	-2	444	-2	440	2	440	2	440	2	442	2
C	C1	-250	1050	-250	1050	-252	1050	-250	1050	-250	1051	-250	1050	-251	1050
	C2	-250	1200	-250	1200	-254	1201	-250	1200	-250	1202	-250	1200	-250	1200
	C3	0	1200	1	1200	3	1201	1	1199	1	1198	1	1199	1	1199
	C4	0	1050	1	1051	3	1051	1	1049	1	1049	1	1049	2	1049
D	D1	410	660	410	660	411	661	410	661	411	661	410	661	412	661
	D2	410	900	410	902	414	902	410	900	413	902	410	900	412	902
	D3	650	900	650	900	650	901	650	899	651	899	650	899	650	902
	D4	650	660	654	661	654	661	654	660	653	665	654	660	654	661
E	E1	410	410	414	410	414	410	414	412	412	412	414	412	412	415
	E2	410	640	410	639	411	639	410	640	412	640	410	642	413	643
	E3	650	640	650	640	652	641	650	640	652	642	651	642	650	641
	E4	650	410	650	410	652	410	650	410	651	411	650	410	650	411
F	F1	340	0	340	1	341	1	340	1	341	2	342	2	342	2

Column	Testing Model	Value Reference (mm)		Testing 1 (10th minute)		Testing 2 (20th minute)		Testing 3 (30th minute)		Testing 4 (40th minute)		Testing 5 (50th minute)		Testing 6 (60th minute)	
		x	y	x	y	x	y	x	y	x	y	x	y	x	y
	F2	340	240	340	240	340	240	340	242	341	242	340	240	340	242
	F3	380	240	381	239	382	239	381	235	378	241	381	235	382	235
	F4	580	0	581	1	583	2	581	2	582	1	581	2	583	2
G	G1	790	110	790	110	788	110	790	112	791	112	790	112	790	111
	G2	790	350	792	352	785	352	792	352	792	352	792	352	792	352
	G3	1030	350	1030	350	1028	350	1030	350	1032	352	1030	350	1030	352
	G4	1030	110	1031	111	1028	112	1031	112	1031	112	1031	112	1031	112
H	H1	790	410	790	410	788	412	790	409	792	405	790	409	790	409
	H2	790	640	790	640	791	641	790	640	791	642	790	641	790	640
	H3	1030	640	1030	640	1030	640	1030	640	1032	643	1030	642	1030	642
	H4	1030	410	1032	413	1030	411	1032	413	1032	413	1032	413	1030	413
I	I1	790	660	790	660	791	660	790	660	790	662	790	660	791	660
	I2	790	900	791	901	791	901	791	902	791	902	791	902	791	902
	I3	1030	900	1030	900	1033	900	1031	902	1031	901	1031	902	1031	902
	I4	1030	660	1032	663	1033	663	1032	663	1032	661	1032	663	1032	663
J	J1	1480	660	1480	660	1477	661	1480	662	1482	663	1480	662	1480	662
	J2	1480	900	1480	900	1478	889	1481	900	1481	899	1481	900	1481	900
	J3	1730	900	1728	899	1730	899	1728	898	1728	898	1728	898	1729	899
	J4	1730	660	1730	660	1730	660	1730	661	1730	661	1730	661	1730	661
K	K1	1480	410	1479	409	1484	409	1475	409	1475	409	1475	409	1472	408
	K2	1480	640	1480	640	1484	640	1480	640	1480	640	1480	640	1480	640
	K3	1030	640	1030	640	1030	640	1030	640	1030	642	1030	640	1030	640
	K4	1730	410	1733	410	1733	410	1732	411	1732	411	1732	411	1732	411
L	L1	1480	111	1480	110	1480	110	1480	110	1480	110	1480	110	1481	111
	L2	1480	350	1480	350	1480	350	1481	350	1481	350	1481	350	1481	351
	L3	1730	350	1730	350	1732	350	1732	350	1732	350	1732	350	1732	352
	L4	1730	110	1730	110	1730	110	1731	110	1731	110	1731	110	1731	112
M	M1	1900	112	1900	110	1902	110	1900	110	1900	110	1900	110	1900	110
	M2	1900	350	1900	350	1903	350	1901	350	1901	350	1901	350	1901	352
	M3	2130	350	2128	350	2126	350	2128	350	2128	350	2128	350	2128	351
	M4	2130	110	2130	110	2131	110	2132	111	2132	111	2132	111	2131	111
N	N1	1900	410	1900	410	1901	410	1902	412	1902	412	1902	412	1901	412
	N2	1900	640	1901	640	1901	640	1901	640	1901	640	1901	640	1902	640
	N3	2130	350	2130	350	2130	350	2130	350	2130	352	2130	350	2133	350
	N4	2130	410	2130	410	2130	410	2130	410	2130	412	2130	410	2132	410
O	O1	1900	660	1910	650	1910	650	1910	650	1910	650	1909	653	1910	652
	O2	1900	900	1901	900	1900	900	1901	900	1901	901	1901	900	1901	900
	O3	2130	900	2130	900	2130	900	2130	900	2130	901	2130	900	2130	902
	O4	2130	660	2132	660	2132	660	2132	660	2132	662	2132	660	2132	660

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Column	Testing Model	Value Reference (mm)		Testing 1 (10th minute)		Testing 2 (20th minute)		Testing 3 (30th minute)		Testing 4 (40th minute)		Testing 5 (50th minute)		Testing 6 (60th minute)	
		x	y	x	y	x	y	x	y	x	y	x	y	x	y
P	P1	410	1060	410	1060	410	1060	410	1060	410	1058	410	1060	410	1062
	P2	410	2030	413	2030	412	2030	413	2030	413	2030	413	2030	413	2030
	P3	780	2030	780	2030	780	2030	782	2032	782	2032	782	2032	782	2032
	P4	780	1375	781	1375	781	1375	781	1375	781	1375	781	1375	781	1375
	P5	1420	1375	1420	1377	1420	1377	1420	1377	1420	1377	1420	1377	1420	1377
	P6	1420	1875	1419	1875	1419	1875	1419	1875	1419	1875	1419	1875	1419	1875
	P7	2060	1875	2059	1886	2059	1886	2059	1886	2059	1886	2059	1877	2059	1882
	P8	2060	1290	2059	1290	2059	1290	2059	1290	2059	1290	2057	1288	2059	1290
	P9	2130	1290	2130	1290	2129	1290	2131	1291	2131	1291	2130	1290	2131	1291
	P10	2130	1210	2130	1209	2129	1209	2129	1208	2129	1208	2129	1209	2129	1207
	P11	2370	1210	2370	1210	2367	1210	2371	1211	2371	1211	2371	1212	2371	1212
	P12	2370	930	2370	931	2371	931	2371	931	2371	931	2372	931	2372	932
	P13	1730	930	1730	932	1732	932	1731	932	1731	932	1732	931	1735	935
	P14	410	1060	410	1061	410	1061	409	1061	409	1059	409	1063	412	1063

Table 4. Solo-Jogja Toll Road Office Error Testing

Column	Testing Model	Value Reference (mm)		Testing 1 (10th minute)		Testing 2 (20th minute)		Testing 3 (30th minute)		Testing 4 (40th minute)		Testing 5 (50th minute)		Testing 6 (60th minute)	
		x	y	x	y	x	y	x	y	x	y	x	y	x	y
1	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0	130	1	132	1	132	1	132	1	130	1	132	2	130
	C	130	130	133	132	132	131	133	132	133	130	133	132	132	132
	D	130	0	132	1	133	3	132	1	132	1	132	1	131	1
4	A	-592	107	-595	110	-590	110	-590	111	-595	112	-592	111	-595	118
	B	-592	212	-591	210	-595	210	-591	210	-591	211	-591	212	-592	209
	C	-462	212	-461	211	-463	212	-461	211	-461	214	-461	211	-461	211
	D	-462	107	-463	108	-463	108	-462	108	-463	105	-463	108	-463	108
5	A	-592	478	-590	474	-590	474	-591	472	-590	473	-590	474	-590	474
	B	-592	628	-591	624	-591	625	-590	624	-593	625	-591	624	-591	622
	C	-462	628	-464	623	-464	623	-464	623	-465	621	-466	623	-464	623
	D	-462	478	-464	474	-466	474	-464	474	-466	474	-461	474	-465	474
8	A	-602	1395	-600	1398	-606	1398	-606	1400	-603	1395	-606	1398	-599	1398
	B	-602	1525	-600	1526	-600	1526	-600	1530	-602	1524	-604	1527	-598	1524
	C	-472	1525	-477	1527	-473	1527	-477	1527	-473	1523	-472	1523	-477	1525
	D	-472	1395	-478	1399	-478	1399	-479	1399	-476	1399	-477	1390	-473	1399

Column	Testing Model	Value Reference (mm)		Testing 1 (10th minute)		Testing 2 (20th minute)		Testing 3 (30th minute)		Testing 4 (40th minute)		Testing 5 (50th minute)		Testing 6 (60th minute)	
		x	y	x	y	x	y	x	y	x	y	x	y	x	y
9	A	-44	1395	-45	1394	-45	1392	-43	1400	-46	1393	-44	1394	-45	1397
	B	-44	1525	-45	1523	-45	1521	-45	1524	-46	1523	-45	1524	-45	1522
	C	86	1525	85	1522	85	1527	85	1519	83	1524	87	1520	85	1522
	D	86	1395	83	1394	83	1393	83	1393	81	1395	83	1396	83	1394
10	A	-44	1887	-42	1884	-42	1884	-42	1880	-43	1884	-45	1884	-42	1884
	B	-44	2017	-41	2012	-45	2014	-41	2012	-45	2012	-41	2012	-41	2013
	C	86	2017	84	2014	84	2014	84	2014	85	2014	84	2014	84	2018
	D	86	1887	85	1883	84	1881	85	1883	85	1883	85	1883	85	1888
11	A	-340	2283	-342	2286	-342	2286	-342	2286	-343	2286	-342	2286	-342	2283
	B	-340	2413	-341	2420	-341	2420	-341	2420	-343	2420	-341	2420	-341	2425
	C	-210	2413	-212	2418	-211	2418	-212	2418	-212	2418	-212	2418	-212	2418
	D	-210	2283	-213	2288	-212	2288	-213	2288	-215	2288	-213	2288	-213	2283
28	A	1655	2283	1652	2290	1657	2294	1652	2290	1652	2290	1652	2290	1652	2291
	B	1655	2413	1654	2420	1656	2422	1654	2420	1654	2420	1654	2420	1654	2423
	C	1785	2413	1789	2411	1789	2412	1789	2411	1789	2411	1790	2412	1789	2411
	D	1785	2283	1783	2284	1783	2281	1783	2284	1783	2284	1783	2286	1783	2284
39	A	3708	2283	3712	2288	3715	2285	3712	2288	3712	2288	3712	2288	3712	2288
	B	3708	2433	3714	2447	3714	2447	3714	2447	3714	2447	3714	2442	3713	2444
	C	3858	2433	3853	2439	3855	2434	3856	2439	3853	2439	3853	2439	3853	2439
	D	3858	2283	3852	2285	3852	2281	3856	2285	3852	2285	3852	2285	3852	2285
42	A	3708	1182	3703	1185	3704	1188	3701	1185	3703	1185	3703	1185	3703	1185
	B	3708	1312	3702	1313	3706	1312	3705	1314	3702	1313	3702	1311	3702	1312
	C	3858	1312	3850	1311	3855	1312	3854	1311	3850	1311	3850	1316	3850	1311
	D	3858	1182	3851	1183	3851	1182	3856	1185	3851	1183	3851	1183	3851	1183
44	A	373	195	372	195	374	195	372	195	372	195	372	195	372	197
	B	373	326	373	324	373	324	375	324	373	324	373	324	375	324
	C	385	326	382	323	385	323	382	323	382	323	382	323	382	323
	D	385	195	386	192	386	192	386	192	386	192	386	192	386	192
47	A	2332	181	2335	184	2335	184	2334	184	2335	184	2335	184	2335	184
	B	2332	341	2336	345	2336	345	2337	345	2336	345	2336	345	2336	345
	C	2492	341	2498	344	2498	344	2500	342	2489	344	2498	344	2498	344
	D	2492	181	2496	183	2496	185	2496	186	2496	183	2499	182	2496	183
48	A	1656	295	1651	290	1651	295	1651	295	1651	290	1651	290	1651	290
	B	1656	425	1652	422	1652	422	1652	425	1652	420	1652	422	1652	422
	C	1786	425	1783	422	1783	422	1788	423	1783	422	1783	422	1783	422
	D	1786	295	1782	293	1782	293	1785	292	1782	293	1782	293	1782	293
49	A	1158	165	1151	162	1151	162	1150	161	1151	162	1151	162	1151	162
	B	1158	295	1154	294	1154	294	1151	293	1154	294	1154	294	1156	294
	C	1288	295	1282	292	1285	292	1282	292	1282	292	1283	290	1281	291
	D	1288	165	1282	166	1286	164	1282	166	1282	166	1282	166	1285	163
50	A	1158	0	1160	0	1167	1	1160	0	1160	4	1160	1	1160	2
	B	1158	130	1159	132	1157	133	1159	132	1159	132	1159	135	1159	132
	C	1288	130	1290	133	1293	133	1290	133	1290	133	1293	133	1290	133
	D	1288	0	1290	2	1291	2	1290	2	1290	5	1290	2	1290	3

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Column	Testing Model	Value Reference (mm)		Testing 1 (10th minute)		Testing 2 (20th minute)		Testing 3 (30th minute)		Testing 4 (40th minute)		Testing 5 (50th minute)		Testing 6 (60th minute)	
		x	y	x	y	x	y	x	y	x	y	x	y	x	y
51	A	763	0	767	2	767	1	767	2	767	4	767	2	767	1
	B	763	130	765	132	765	132	765	132	765	132	764	132	765	132
	C	893	130	895	133	893	132	895	133	895	133	895	133	894	131
	D	893	0	890	1	893	1	890	1	890	1	895	1	890	1
52	A	516	0	520	3	526	2	520	3	520	3	519	2	521	1
	B	516	130	521	126	520	125	521	126	518	122	521	126	521	126
	C	646	130	642	125	642	123	642	125	643	124	642	125	643	122
	D	646	0	643	2	640	1	641	3	644	2	641	3	649	2

4.5. Result of Average Error

The average error can be computed by summing the total error and dividing it by the number of coordinate points. The average building errors are presented in Tables 5 and 6 below:

Table 5. Total error calculation result of IKN Minister's Residence Building (%)

Error	Value (%)
Total Error in Testing 1	0,5067567568
Total Error in Testing 2	0,5608108108
Total Error in Testing 3	0,4797297297
Total Error in Testing 4	0,7702702703
Total Error in Testing 5	0,4864864865
Total Error in Testing 6	0,8851351351
Total Error	0,6148648649

Table 6. Total error calculation result of Solo-Jogja Toll Road Office (%)

Error	Value (%)
Total Error in Testing 1	0,6838235294
Total Error in Testing 2	0,3823529412
Total Error in Testing 3	0,6176470588
Total Error in Testing 4	0,8382352941
Total Error in Testing 5	0,5735294118
Total Error in Testing 6	0,5661764706
Total Error	0,6102941177

5. Conclusion

Based on the conducted research, it can be concluded that the implementation of Augmented Reality technology for building coordinate determination results in a total error value of 0.61% for the IKN Residence and 0.61% for the Solo-Yogyakarta Toll Office buildings. The Augmented Reality technology employed in this study has proven to be reliable for determining the coordinates of building components.

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