**TITLE:** Major Opportunities of Digital Twins for Smart Building: A Scientometric and Content Analysis

**Appendix**

**A1: 56 Themes/keywords reflecting opportunities of digital twins for smart buildings**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **ID** | **Themes** | **Link Strength** | **Occurrences** | **Avg. pub. Year** | **Avg. citations** | **Avg. norm. citations** |
| 1 | Virtual reality | 8 | 2 | 2019.5 | 9.5 | 2.4 |
| 2 | Cost effectiveness | 6 | 1 | 2021 | 14 | 1.0667 |
| 3 | Information analysis | 6 | 1 | 2021 | 14 | 1.0667 |
| 4 | Information communication | 6 | 1 | 2021 | 14 | 1.0667 |
| 5 | Information dissemination | 6 | 1 | 2021 | 14 | 1.0667 |
| 6 | Information sharing | 6 | 1 | 2021 | 14 | 1.0667 |
| 7 | Innovative solutions | 6 | 1 | 2021 | 14 | 1.0667 |
| 8 | Transparency | 6 | 1 | 2021 | 14 | 1.0667 |
| 9 | Data integration | 5 | 2 | 2020 | 6 | 0.4613 |
| 10 | Gesture control | 5 | 1 | 2017 | 18 | 1.8 |
| 11 | Human-robot collaboration | 5 | 1 | 2017 | 18 | 1.8 |
| 12 | Minimal energy | 5 | 1 | 2017 | 18 | 1.8 |
| 13 | Modularizations | 5 | 1 | 2017 | 18 | 1.8 |
| 14 | Simultaneous control | 5 | 1 | 2017 | 18 | 1.8 |
| 15 | Accident prevention | 4 | 1 | 2021 | 14 | 1.0667 |
| 16 | Human-computer interaction | 4 | 1 | 2021 | 14 | 1.0667 |
| 17 | life-cycle management | 4 | 1 | 2021 | 14 | 1.0667 |
| 18 | Performance monitoring | 4 | 1 | 2021 | 14 | 1.0667 |
| 19 | Real-time control | 4 | 1 | 2021 | 14 | 1.0667 |
| 20 | Building automation | 3 | 1 | 2020 | 0 | 0 |
| 21 | Critical analysis | 3 | 1 | 2019 | 17 | 1.3421 |
| 22 | Design optimization | 3 | 1 | 2021 | 8 | 0.6095 |
| 23 | Efficient construction | 3 | 1 | 2019 | 17 | 1.3421 |
| 24 | Improve speed | 3 | 1 | 2021 | 8 | 0.6095 |
| 25 | Informed decision | 3 | 1 | 2019 | 17 | 1.3421 |
| 26 | Intelligent buildings | 3 | 1 | 2020 | 0 | 0 |
| 27 | Physical modeling | 3 | 1 | 2022 | 1 | 3 |
| 28 | Planning and designing | 3 | 1 | 2021 | 9 | 0.6857 |
| 29 | Rapid transformations | 3 | 1 | 2019 | 17 | 1.3421 |
| 30 | Real-time connections | 3 | 1 | 2020 | 0 | 0 |
| 31 | Real-time information | 3 | 1 | 2022 | 1 | 3 |
| 32 | Security Solutions | 3 | 1 | 2021 | 8 | 0.6095 |
| 33 | Smart space | 3 | 1 | 2020 | 0 | 0 |
| 34 | Speed accuracy | 3 | 1 | 2021 | 8 | 0.6095 |
| 35 | Sustainable decision makings | 3 | 1 | 2021 | 9 | 0.6857 |
| 36 | Systems thinking | 3 | 1 | 2021 | 9 | 0.6857 |
| 37 | Virtual representations | 3 | 1 | 2022 | 1 | 3 |
| 38 | Automated construction | 2 | 1 | 2020 | 2 | 0.099 |
| 39 | Building information modeling | 2 | 1 | 2020 | 2 | 0.099 |
| 40 | Information integration | 2 | 1 | 2019 | 3 | 0.2368 |
| 41 | Information retrieval | 2 | 1 | 2019 | 3 | 0.2368 |
| 42 | Maintenance | 2 | 1 | 2020 | 83 | 4.1089 |
| 43 | Operators’ safety | 2 | 1 | 2020 | 83 | 4.1089 |
| 44 | Remote control | 2 | 1 | 2020 | 2 | 0.099 |
| 45 | Risk assessment | 2 | 1 | 2020 | 83 | 4.1089 |
| 46 | Building management system (BMS) | 1 | 1 | 2021 | 0 | 0 |
| 47 | Interoperability | 1 | 2 | 2019 | 9.5 | 0.7476 |
| 48 | Real-time monitoring | 1 | 1 | 2020 | 1 | 0.0495 |
| 49 | Smart building | 1 | 1 | 2021 | 0 | 0 |
| 50 | Smart city | 1 | 1 | 2021 | 17 | 1.2952 |
| 51 | Smart construction | 1 | 1 | 2020 | 1 | 0.0495 |
| 52 | Tracking simulation | 1 | 1 | 2021 | 1 | 0.0762 |
| 53 | Tracking strategies | 1 | 1 | 2021 | 1 | 0.0762 |
| 54 | Digital information flow | 0 | 1 | 2019 | 18 | 1.4211 |
| 55 | Digital transformation | 0 | 1 | 2022 | 0 | 0 |
| 56 | Semantic modeling | 0 | 1 | 2020 | 15 | 0.7426 |