Review

Reviewing the Role of Key Performance Indicators in Architectural and Urban Design Practices

Supplementary Materials

List of KPIs found in literature divided into eight clusters

1. Indoor comfort KPIs:

1.1 Indoor thermal comfort/thermal comfort score (PMV, PPD, % in Class I, II, III according to EN 1525, 1-LPD)
1.2 Indoor air quality (IAQ % out of class according to EN 15251)
1.3 daylight factor (0<DF<5)
1.4 daylight requirement (% ≥ 1, % ≥ 10)1.5 view out quality (% of openings area on façade regarding adjacent building)
1.6 layout (To be advised)
1.7 Daylight Usage (-)
1.8 Temperature Control (°C)
1.9 Water Consumption (L) 1.10 Noise pollution (Tenant satisfaction)
1.11 Visual comfort (cd/m2)
1.12 Local temperature deviation (-)
1.13 Indoor occupancy (%)
1.14 Space height (m)
1.15 Flexibility of spaces (-)
1.16 Discomfort hours (27-28°C) (number of hours)
1.17 Thermal Load Score (temperature difference of in- and out-streaming air bodies)
1.18 Inlet temperature (°C)
1.19 Temperature forecast (°C)
1.20 Average daylight factor/Daylight Illuminance (DF, UDI 20-1000 Lux)
1.21 Natural ventilation (m3/h)
1.22 Indoor Environmental Quality (IEQ) - Health and Wellbeing (IEQ)

2. Energy related KPIs

2.1 Energy consumption/demand (kWh)
2.2 Daily energy use (kWh)
2.3 Daily peak demands (kW)
2.4 Energies Storage system (type of system)
2.5 Renewable Energy Sources (percentage of renewable energies used in production compared to the total energy used in production)
2.6 Electricity consumption (kWh)
2.7 Fuel consumption (litres)
2.8 Daily cooling usage (kWh per day)
2.9 Final Energy consumption (kWh)
2.10 Peak load and profile of electricity demand (kWh)
2.11 Peak load and profile of thermal energy demand(kWh)
2.12 Degree of energetic self-supply(%)
2.13 Net fossil energy consumed (kWh)
2.14 Total energy used per capita (kWh)

2.15 Total residential electrical energy use per capita (kWh)
2.16 Energy demand covered by renewable sources(kWh)
2.17 Total residential natural gas energy use per capita (kWh)
2.18 Total residential butane gas energy use per capita (kWh)
2.19 Energy consumption of public buildings per year(kWh)
2.20 Energy use from district heating, biomass sources, PV sources, solar thermal hydraulic, wind sources, geothermal (-)
2.21 Primary energy consumption(kWh)
2.22 Embodied energy of refurbishment scenarios (MJ/kg)
2.23 Energy payback time (year)
2.24 Energy-Resources Efficiency (ERE) (VR/TR)
2.25 Aggregated operating hours of FCUs(h)
2.26 Ratio of AC-on days/ Daily AC-on duration (-)
2.27 Coincident use factor of FCUs(-)
2.28 Average cooling load per FCU (kWh)
2.29 average thermal power for heating and cooling (kWh)
2.30 self-consumption (0<SC<1, %)
2.31 self-sufficiency (%)
2.32 Overheating hours (weighted), (hours)
2.33 Under-heating hours (weighted) (hours)
2.34 Expected sef-consume (kWh)
2.35 Total cooling consumption (kWh)
2.36 Thermal Storage Score(heat energy storage in materials within project area)
2.37 Application of energy management systems (-)
2.38 Energy Consumption Performance coefficient (-)
2.39 Costs of Energy Consumed (-)
2.40 Comfort, security and health performance score (-)
2.41 Energy Conversion Efficiency (ECE) (-)
2.42 Energy conversion rate (-)
2.43 Local energy production Capacity (kWh)
2.44 Energy frames defined in BR18 (Renovation energy classes (I and II) in kWh/m2/year)
2.45 Utilization ratio (-)
2.46 Life-time energy generating
2.47 System efficiency (-)
2.48 Energy and Natural Resources (-)

3. Economic KPIs:

3.1 Initial costs ($)
3.2 Investment costs ($)
3.3 Building management strategies (percentage of projects in maintenance status that use this type of strategy compared to the total of projects in maintenance status)
3.4 Bills ($)
3.5 Taxes ($)
3.6 Cost in use ($)
3.7 Cost of repair/maintainance ($)
3.8 Economic Operational energy cost ($)
3.9 Investments ($)
3.10 Life cycle cost ($)
3.11 Return on investment(-)
3.12 Payback period (time)
3.13 energy costs (eur/kW)
3.14 expenses on material
3.15 total cost of ownership ($)

3.16 energy costs ($)
3.17 Consideration of enhanced productivity and effectiveness of environments (-)
3.18 Application of efficient management of resources (-)
3.19 Application of integrated facility management (-)
3.20 Consideration of cost/time saving strategies (-)
3.21 Net public finance (-)
3.22 Economic opportunities (-)
3.23 Economic performance and affordability (-)
3.24 Whole Life Value ($)
3.25 at or below the approved cost limit (-)
3.26 minimal variation in cost against budget (-)
3.27 life cycle cost minimized (-)
3.28 a functional building/maintenance product (-)
3.29 (Actual cost–planned cost)/(additional cost for BIM implementation) (-)
3.30 Amount of change measured as change order cost over total contract cost (-)
3.31 Cost conformance for major activities (-)
3.32 Total cost conformance (-)

4. Social KPIs:

4.1 Degree of satisfaction (According to percentage of the hours in Temperature + Airflow classes)
4.2 Wellbeing (% regarding Energy improvement, indoor thermal comfort, air quality and their effects on Asthma, Allergy, and Eczema disease)
4.3 Degree of privacy (% of openings area on façade regarding adjacent building)
4.4 Accessibility (-)
4.5 Satisfaction with neighborhood (%)
4.6 Social Energy poverty measured as % of inhabitants that use more than 10% of their incomes to pay energy bills (%)
4.7 Symbolism (-)
4.8 Consideration of the requirements and expectations of occupants and/or users (-)
4.9 Consideration of comfort, convenience, safety and security (user satisfaction %)
4.10 Adaptable to ever-expanding and changing human needs (-)
4.11 Responsive to social and technological changes (-)
4.12 Responsive to the needs for communication and globalization (-)
4.13 Consideration of well-being, emotional satisfaction, and enhanced creativity of users (-)
4.14 Use of self-support of user activity (-)
4.15 Health issues (% regarding Energy improvement, indoor thermal comfort, air quality and their effects on Asthma, Allergy and Eczema diseases)
4.16 Security (-)
4.17 Transport and Accessibility (-)
4.18 Meets the client's needs with minimal rework (making good defects and material waste) (-)
4.19 health and safety design and inspections to minimise accidents (employee well-being) (-)
4.20 Comfort, security and health performance score (-)

5. Environmental KPIs:

5.1 Carbon absorption by trees (g)
5.2 Radiation: sum of shortwave radiation coming into project area (kWh)
5.3 Albedo: average albedo of the project area (0,1-0,8)

5.4 Evapotranspiration: evaporation of soil and transpiration of plants (mm)
5.5 Shading Area Factor: ratio of shaded area (-)
5.6 Leaf Area: sum of total leaf area (m)
5.7 Wind Flow Map: direction and velocity of wind at 15:00 (m/s)
5.8 Run-Off Score: proportion of retained rainwater to project area (%)
5.9 Carbon Sequestration Score: storage of CO2 by green infrastructure in project area (-)
5.10 CO2/GHG emission (CO2 per MWh)
5.11 Solid waste (kg)
5.12 Environmental Global warming potential (GWP) (CO2 eq/m2)
5.13 GWP investment (-)
5.14 GWP reduction (%)
5.15 Urban Percentage of buildings compliant with EPBD standard (%)
5.16 Percentage of buildings compliant with Passivhaus standards (%)
5.17 Percentage of buildings compliant with EnerPhit standards (%)
5.18 Percentage of buildings compliant with nZEB standards (%)
5.19 Global kWh Energy saved/Euro invested, CO2 saved/Euro invested (kWh/eur)
5.20 Eco efficiency (-)
5.21 Solar radiation (kWh/m2)
5.22 Solar angle (°)
5.23 Air pollution
5.24 Embodied energy (MJ/kg)
5.25 Water and Water Conservation (L)
5.26 Materials used, Durability and Waste (-)
5.27 Land use and Site selection (-)
5.28 water consumption and waste (L/m3)
5.29 Anthropogenic heat (J)

6. Architectural KPIs:

6.1 "Designing for deconstruction" strategies (percentage of projects that use them compared to the total number of projects)
6.2 Initiatives in materials manufacturing for sustainable production (percentage of materials used by these initiatives compared to the total of materials used)6.3 layout(to be advised)
6.4 floor area(m2, m2/occupant)
6.5 Blind angle status (°)
6.6 Blind position status(location)
6.7 Architectural form (-)
6.8 Age of property(-)
6.9 refurbishment history(-)
6.10 service charges (-)
6.11 potential for conversion/adaptation(-)
6.12 repairs history (-)
6.13 voids(-)
6.14 view-out quality (-)
6.15 Functionality, Usability and Aesthetic aspects (F) (-)
6.16 Architectural considerations – cultural heritage integration and the compatibility with local heritage value (-)
6.17 Flexibility & Adaptability (-)
6.18 a functional building/maintenance product (-)
6.19 Buildings density and canyons geometry (-)
6.20 Distribution of vegetation qualitative (-)

7. Building technical KPIs:

7.1 average thermal transmittance (W/m2K)
7.2 ventilation heat losses (L/hour)
7.3 solar heat gains (-)
7.4 internal heat (J)
7.5 superficial mass (kg/m2)
7.6 decrement factor (-)
7.7 Time lag (h)
7.8 internal areal heat capacity, k1heat transfer coefficient for envelope transmission (kJ/m2K)
7.9 heat transfer coefficient for ventilation (W/m2)
7.10 global heat transfer coefficient (transmission + ventilation) (W/m2)
7.11 effective thermal capacity(J/K)
7.12 average outdoor air temperature (°C)
7.13 average free-running temperature (°C)
7.14 Physical load index (-)
7.15 Thermal transmittance (W/m2K)
7.16 Utilization of advanced embedded systems for building components (-)
7.17 fixtures and fittings (-)
7.18 Major components (-)
7.19 minor components (-)
7.20 new technologies (-)
7.21 day-to-day repairs (-)
7.22 Boiler status(-)
7.23 Incorporation of intelligent technologies and economic principles (-)
7.24 Application of building systems and technological integrations (-)
7.25 Application of up-to-date adaptable and interoperable building control systems (-)
7.26 Productivity of lean construction (Lean Construction Productivity Potential)
7.27 Building Manageability (-)

8. Other KPIs:

8.1 Decision accuracy of demolition time (percentage of projects designed with these characteristics, compared to the total of projects designed)
8.2 Transition to another loop (percentage of projects designed with these characteristics, compared to the total of projects designed)
8.3 security (-)
8.4 location (-)
8.5 obsolescence/life cycle analysis(-)
8.6 changes to legislation(-)
8.7 Distance/Travel times (hour)
8.8 borough spread(-)
8.9 Number of breakdowns (n)
8.10 ease of repair(-)
8.11 length of tenancy (-)
8.12 Cross-Docking Facility (CFD)(-)
8.13 Warehousing Strategy and Roadmap (WSR) (-)
8.14 Electrical System Hazard, Disturbance caused by electrical system(-)
8.15 Schedule(-)
8.16 Blind remote/manual (-)
8.17 Resources Productivity (VO/TR)
8.18 Resources Intensity (TR/TH)
8.19 Output Intensity (VO/TH)
8.20 Individual control (-)
8.21 % Outside range (%)

8.22 AHU status fan (-)
8.23 Intertwined with advanced sensors and artificial intelligence (-)
8.24 In line with innovative future technologies and upgrades (-)
8.25 System operating for 2 days without charge (-)
8.26 Availability (-)
8.27 Percentage of commuters using a travel mode to work other than a personal vehicle (%)
8.28 4 Kilometers of bicycle paths and lanes per 100 000 population (n)
8.29 Percentage of population living within 0,5 km of public transit running at least every 20 min during peak periods 4 (%)
8.30 Affordability of public transport for the poorest group (-)
8.31 Intermodal connectivity (-)
8.32 Annual number of public transport trips per capita (n)
8.33 Number of personal automobiles per capita rate (n)
8.34 Uptake of active commuting (-)
8.35 Intermodal integration (-)
8.36 Mobility space usage (-)
8.37 Transport applications and digital capabilities (-)
8.38 Average commute time (-)
8.39 Kilometers of public transport system per 100 000 population (km)
8.40 Modal split of trips taken (-)
8.41 Congestion and delays (-)
8.42 Airport passengers (n)
8.43 Number of two-wheel motorized vehicles per capita (n)
8.44 Transportation deaths (fatalities) per 100 000 population (n)
8.45 Innovation and design process (-)
8.46 Communications and mobility (-)
8.47 Intelligence and controllability (-)
8.48 Green public transport penetration qualitative (-)
8.49 Presence of ICT devices (-)
8.50 Innovative environment: presence of innovative technologies /services/ participatory approaches at the district level (-)
8.51 Average response time to RFIs (or submittal approval) (-)
8.52 Number of change orders in project (n)
8.53 Number of errors and omissions in field (n)
8.54 Number of reworks (n)
8.55 Number of RFIs (n)
8.56 Number of risk factors detected using BIM (n)
8.57 Percentage of activities completed without schedule delay (%)
8.58 Rate of passed initial inspections (n)
8.59 Schedule conformance of major activities (-)
8.60 Total schedule conformance (-)

Table S1. List of KPIs used in each paper

Author(s)	Main aim	KPI
[1]	building restoration	• 1.1, 1.2, 1.3, 1.4, 1.5, 1.16 • 2.1 • 3.2 • 4.1, 4.2, 4.3
[2]	reduce building energy demand	• 2.2, 2.3
[3]	Promote energy efficiency	• 2.38, 2.39, 2.40, 2.41 • 4.20
[4]	Promote energy efficiency	• 1.20 • 2.1 (annual) • 3.1
[5]	Promote energy efficiency	• 1.1 • 2.30, 2.43 • 3.13
[6]	Promote sustainable development	X
[7]	remanifacturing	X
[8]	Building restoration	• 1.1, 1.2, 1.3, 1.4 (according to…BR18), 1.16 • 2.1, 2.44 • 3.2, • 4.1, 4.2
[9]	Building restoration	• 1.1, 1.2, 1.3, 1.4, 1.16, • 2.1, 2.48, • 3.2, • 4.15, 4.3 • 5.24, • 6.14 • 7.26
[10]		• 2.47 • 3.21, 3.22 • 4.4, 4.16, 4.2 • 5.10, 5.23 • 8.27, 8.28, 8.29, 8.30, 8.31, 8.32, 8.33,… 8. 44
[11]	KPIs for circular economy	• 2.5 • 3.3 • 6.1, 6.2 • 8.1, 8.2
[12]	Sustainable maintenance and refurbishment	• 1.1, 1.6, 1.10, 1.13 • 2.29 • 3.4, 3.5, 3.6, 3.7 • 4.4, 4.5 • 6.3, 6.4, 6.8, 6.9, 6.10, 6.11, 6.12, 6.13 • 7.17, 7.18, 7.19, 7.20, 7.21 • 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 8.10, 8.11

[13]	Post-contract design sustainability control	• 1.2 • 2.1 • 3.25, 3.26, 3.27, 3.28 • 4.18, 4.19 • 5.10, 5.28 • 6.18
[14]	Optimization of performances of PV panels	• 2.30, 2.31, 2.34 • 3.16 (expected)
[15]	KPIs to measure sustainability	• 1.7, 1.8, 1.9, 1.10 • 2.4, 2.5 • 5.1 • 7.14 • 8.12, 8.13, 8.14
[16]	Urban energy balance	• 1.1, 1.17 • 2.36 • 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9
[17]	accelerate the transition towards a sustainable future	• 2.6, 2.7 • 5.10, 5.11
[18]	Reduce energy use	• 2.8, 2.25, 2.26, 2.27, 2.28, 2.29, 2.35
[19]	Energy saving	• 1.1, 1.2, 1.11 • 2.1, 2.9, 2.10, 2.11, 2.12, 2.13, 2.14, 2.25, 2.16, 2.17, 2.18, 2.19, 2.20, 2.21, 2.22, 2.23 • 3.8, 3.9, 3.10, 3.11, 3.12 • 4.6 • 5.12, 5.13, 5.14, 5.15, 5.16, 5.17, 5.18, 5.19 • 8.21
[20]	Improve building's performance in terms of energy use	• 1.1, 1.3, 1.13, 1.18, 1.19 • 5.21, 5.22, • 6.5, 6.6 • 7.22, 7.23, 7.24 • 8.15, 8.16, 8.22
[21]		• 2.44, 2.45, 2.46, 2.47 • 3.12 • 5.10 • 8.25, 8.26
[22]		• 1.1 • 2.1, 2.5 (percentage in relation to total consumption) • 5.4, 5.23, 5.29 • 6.19, 6.20 • 8.48, 8.49, 8.50
[23]	Limit energy use and losses	• 7.1, 7.2, 7.3, 7.4
[24]	Define common features of IB (intelligent buildings)	• 2.5, 2.37

		• 3.10, 3.15, 3.17, 3.18, 3.19, 3.20 • 4.10, 4.11, 4.12, 4.13, 4.14, 4.15 • 5.20 • 7.16, 7.23, 7.24, 7.25 • 8.23, 8.24
[25].	Bim	• 3.29, 3.30, 3.31, 3.32 • 8.51, 8.52, 8.53, 8.54, 8.55, 8.56, 8.57, 8.58, 8.59, 8.60
[26]		• 2.1 • 4.1 • 5.11
[27]	Improve performances of plants	X
[28]	Multiscale analysis of the building	• 2.29 • 5.21 (daily) • 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13, 7.15
[29]	Improve eco-efficiency	• 2.1, 2.16, 2.17, 2.18 • 3.7, 3.16 • 5.10
[30]	Optimization of processes and reduction of waste	• 2.24 • 5.20 • 8.17, 8.18, 8.19
[31]	Optimization of NZEB building	• 2.1 • 1.3, 1.21
[32]	Sustainable energy use	X
[33]	Improve building's performance ALSO in terms of energy use	• 1.1, 1.13, 1.14, 1.15, 1.32, 1.33 • 3.1 • 4.7 • 6.7 • 8.20
[34]	Improve energy efficiency	• 2.1
[35]	Improve urban and building performance	X
[36]	Improve building performance	• 1.22 • 2.48 • 3.23, 3.24 • 4.17 • 5.10, 5.25, 5.26, 5.27 • 6.15, 6.16, 6.17 • 7.27 • 8.45, 8.46, 8.47

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