CASE STUDY 1-12: SALAM CARDIAC SURGERY CENTRE | SUDAN

GEOGRAPHICAL AND CLIMATE INFORMATION	
Location	Soba, Khartoum, Sudan
Latitude; Longitude	15.509919818764784, 32.66305412641556
Climate zone (Köppen–Geiger classification)	BWh: Hot desert
BUILDING INFORMATION [1][2]	
Building Type	Hospital
Project Type	New construction
Completion Date	2010
Number of buildings	1
Number of storeys	1
Total Floor Area (m²)	12.000
Net Floor Area (m²)	-
Thermally conditioned space area (m²)	9.300 (ground floor + basement)
Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m²)	2.700
Total cost (€)	15 920 960
Cost /m² (€/m²)	1 137,2
Performance Standards or Certification	None
Awards	Aga Khan Award for Architecture
STAKEHOLDERS [1][2]	
Building Owner/ Representative	Emergency NGO - Pietro Parrino, Rossella Miccio
Architect / Designer	Studio Tamassociati - Raul Pantaleo, Simone Sfriso, Massimo Lepore, Sebastiano Crescini with Pietro Parrino and Gino Strada
Construction manager	-
Environmental consultancy	-
Structural Engineer	Francesco Steffinlongo
Mechanical/services engineering	Studio Pasquini with Jean Paul Riviere and Nicola Zoppi

Product Manufacturer	-
Certification company	-
Others	Franco Binetti (Operating Theatre design) Roberto Crestan with Alessandro Giacomello (Site engineer)

PROJECT DESCRIPTION

Figure 172: Reception area of the Salam Cardiac Surgery Centre

The Salam Cardiac Surgery Center is located in Soba Hill, 18 km from the city of Khartoum, in Sudan. It consists of a 63-bed hospital with 300 local staff, with a separate medical staff accommodation complex that can accommodate 66 people. This centre is built as a pavilion in a garden with the two main buildings organized around large courtyards. [1]

The design of the SALAM cardiac surgery centre followed three main guiding principles [3]:

- the idea of a “hollow” space and a pavilion-based system;
- the choice of the best possible technology given the context;
- the search for an ethical language for this type of architecture.

Figure 173: Salam Cardiac Surgery Centre exterior view

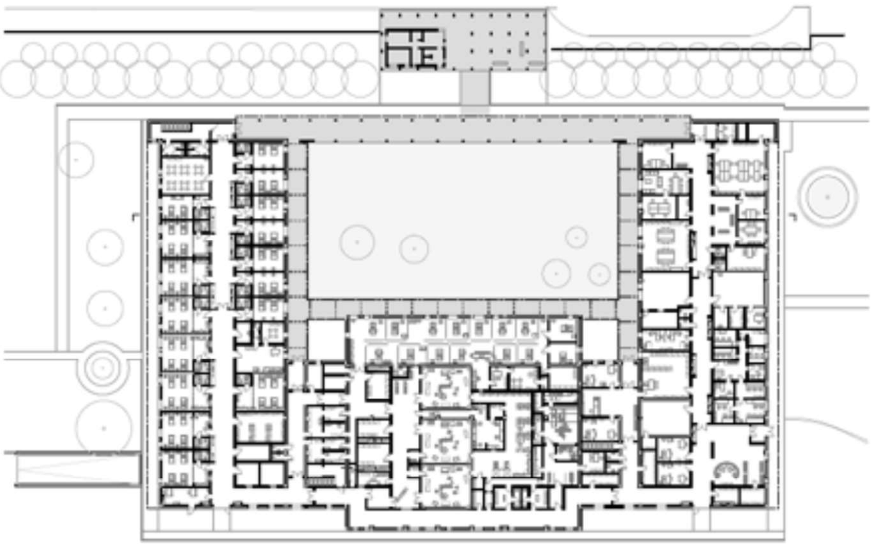

Figure 174: Floor plan of the building

SITE INTEGRATION

Figure 175 : Aerial view of the building and its' surrounding

The hospital surroundings are mainly desert areas, with no vegetation. The hospital was developed around an empty space, physically and ideally occupied by two huge mango trees, located in the center of the site (a plot on the banks of the Nile about 20 km from Khartoum). In keeping with traditional housing structures, the hospital is configured around a hollow space, creating angles, perspectives and sensations that change forever and are never monotonous.

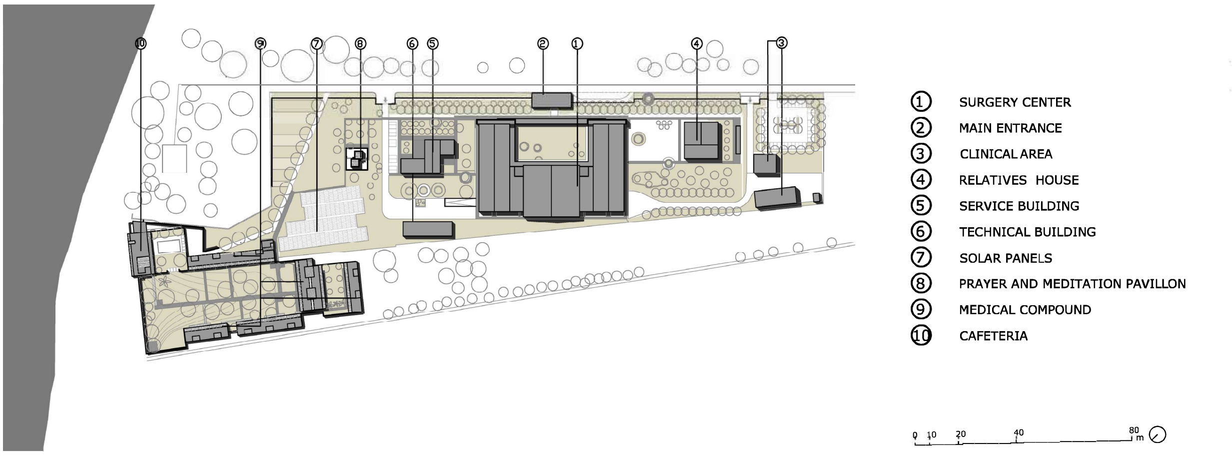

Figure 176: Site plan of the "Salam" centre [3]

CLIMATE ANALYSIS

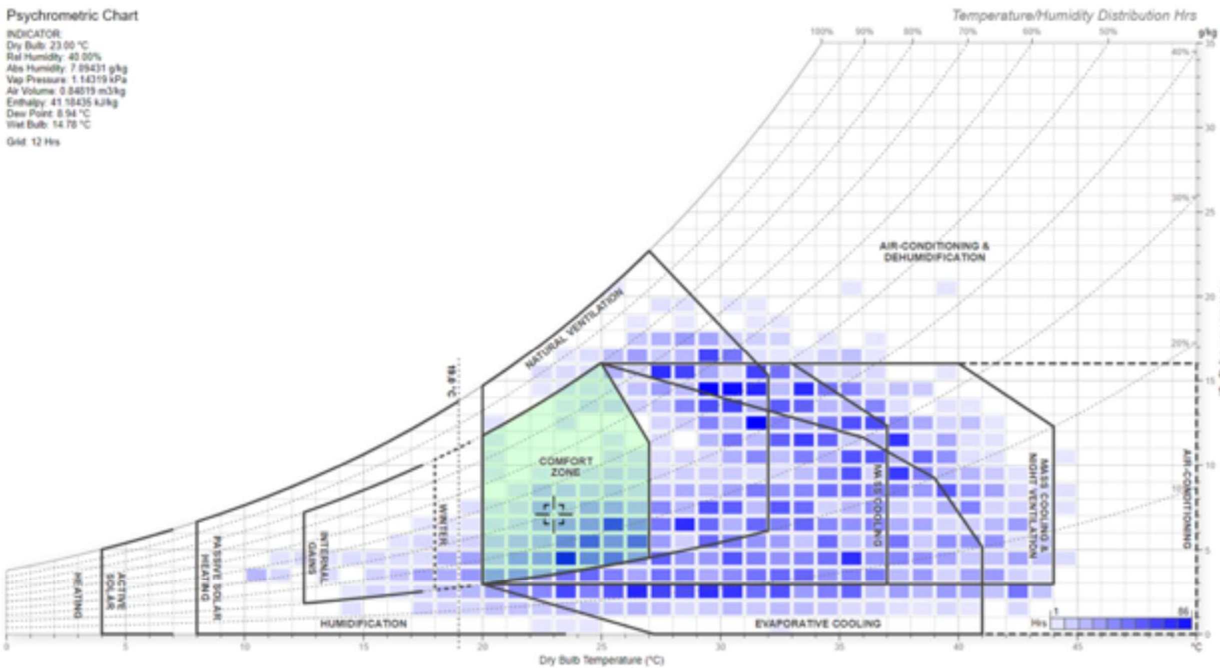

Figure 177: Bioclimatic chart for the climate of Khartoum using Andrew Marsh online tool [4]. Climate data are extracted from http://climate.onebuilding.org/WMO_Region_1_Africa/SDN_Sudan/KS_Kush/SDN_KS_Khartoum.Intl.AP.627210_TMYx.2004-2018.zip

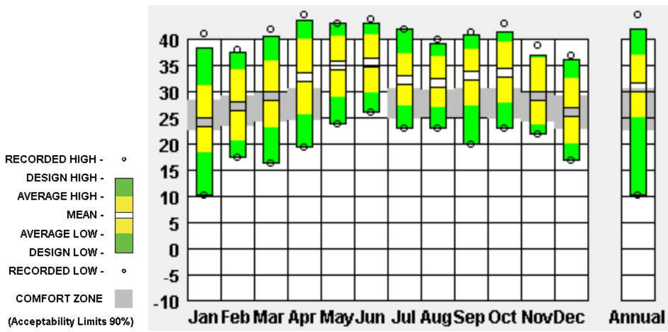

Figure 178: Temperature range by month of Khartoum. Source: Climate consultant – Adaptative Comfort model [5]

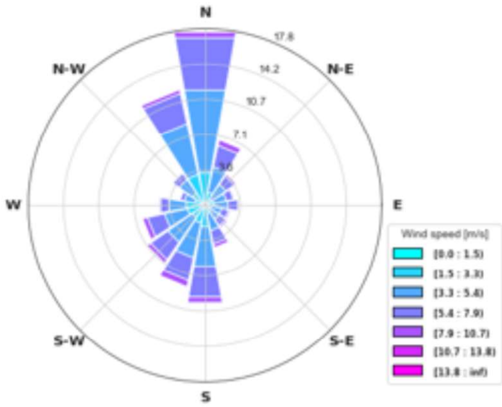

Figure 179: Annual wind rose for Khartoum (Beaufort wind scale) [5]

Global horizontal radiation (Avg daily total) Min (month) / Max (month)	Min: **5547** Wh/m² (Jan) Max: **7431** Wh/m² (May) Mean: **6532,33** Wh/m²
Annual Degree-Days for weather classification according to ASHRAE Standard 169-2020	HDD 18°C: **16** CDD 10°C: **7 607**
Annual Degree-Days for the Adaptive Comfort Base Temperature according to the ASHRAE 55-2017 for 80% of acceptability	HDD: **84** CDD: **810**
Annual Degree-Days for a static comfort temperature approach	HDD 18.6ºC: **21** CDD 26º: **2 033**

KEY BIOCLIMATIC DESIGN PRINCIPLES [3]	
Passive cooling strategy	Comfort ventilation: natural cross-ventilation Mass cooling (60cm thick brick walls) Mixed modes of ventilation (NV & air conditioning) Thermal break windows Roof insulation
Passive heating strategy	NA
Solar protection	Bamboo blinds
Building orientation	The main facades of the building are oriented North/West
Insulation	A highly performing wall made of two layers of bricks separated by an insulating air cavity, with small windows. These windows are closed by highly performing glass panels with low emissions. The external walls are 58cm thick and contain an insulated cavity that prevents the building from heating up. Insulation is also through an onion system of 5-centimetre internal insulating panels and an outer skin comprising a ventilated metal roof and bamboo blinds.
Vegetation	Shrubs and trees were used to protect the buildings from the heat and to mitigate the effects of the harsh climate.
Natural daylighting	All living spaces have natural light.

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Use of local and embedded materials	Bamboo
Water saving and heat recovery on hot water drain	The production of hot water and heat are satisfied 100% by renewable energy without the need for recovery.
Waste management	The complete waste cycle is not managed internally.
Others features	A simple, mechanical solution was found so as to filter the large quantities of dust and sand in the air without having to rely on costly and complicated filtering devices. The air is designed to pass through a series of tunnels- a labyrinth like structure- before reaching the Air Handling Unit By doing so, the impact of the air on the walls of the tunnel will allow the sand to sediment while at the same time cooling the air by reducing its speed. A fine spray of water in the middle of the tunnels further eliminates the finer dust from the air and cools it down even more. The system needs very little maintenance work- limited to cleaning the tunnel-like structure- and allows the air to reach the conditioners filtered and 12°C cooler than when it enters the system.

Figure 180: Vegetation and shaded waiting area of the Salam Cardiac Surgery Centre Sudan

INFRASTRUCTURES and REGULATIONS to enable SUFFICIENCY ACTION	
Dressing code	Informal dressing, adapted to the season, is welcome and promoted (e.g. short trousers and short leaves in hot periods): No
Protected bike parking and showers	Bikes are not used in Sudan. Ratio with number of users: NA
Ceiling fans	In every room, even those conditioned: No. Ceiling fans are only present in the canteen and the guest house.
Lighting system fractioned to allow using light only in zones occupied and where daylighting insufficient	In every room, even those conditioned: Yes. The lights circuit is divided for the different areas and can be manage according to the day light and the occupancy
Space and facilities for line drying clothes (especially important in residences, hotels, sport facilities…)	In every room, even those conditioned: Unknown
Book of instruction for correct use of the passive features (windows, solar protections, water savings) and active (lighting…) in order to promote sufficiency and efficiency actions	Available through leaflets and posters at relevant places, online, etc.: Unknown

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BUILDING FABRIC AND MATERIALS	
Roof	Insulated corrugated sheet Traditionally crafted thatched roofs for paths and areas for rest.
	Overall R-value:-
Windows	Windows aluminium 55 mm, Venetian blind inserted in the double glazing, 6+12+6 mm
	Window-to-wall ratio (WWR): -
	U-value: -
	Visual transmittance: -
Walls	Walls are made of two layers of bricks separated by an insulating air cavity, with small windows. Thickness: 58cm
	Overall R-value: -

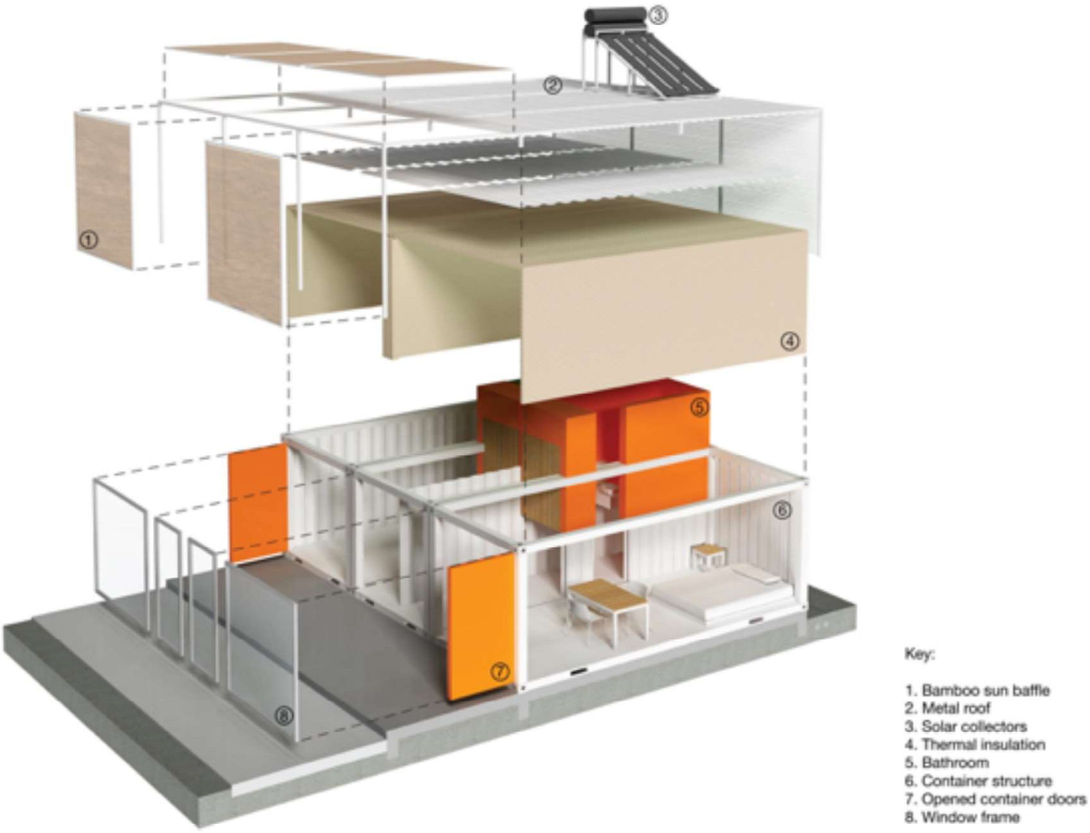

Figure 181 : Exploded view of the building fabric.

Figure 182: Bamboo sun and dust baffle

ENERGY EFFICIENT BUILDING SYSTEMS [3]	
Low-energy cooling systems	Solar collecting items are made up of a number of copper tubes that contain water; these are themselves placed in insulated glass tubes that allow the water inside the copper tubes to heat up. The water transfers the accumulated heat to an insulated 50m3 tank that keeps the water at 80-90°C. The heat is then cooled down to 7°C in two “chilling” machines. [3] Solar power thus allows to produce cold without discharging any particles in the atmosphere, and limiting the use of electric power to water circulation pumps. Two regular boilers have also been installed in case the solar power is not sufficient to run the two “chilling” machines. The cold water is used to lower the levels of heat in the rooms that need to be chilled for medical or other purposes. The machines used for this last part of the cooling circuit are called AHU (Air Handling Unit). There are 8, each one designed for a specific area of the hospital (surgery, administration, etc). The AHU draw air from outside and “force” it into a 7°C tube that cools it down. A second system of tubes subsequently transports the cool air to various hospital rooms according to need. [3]
Low-energy heating systems	NA
Ceiling fans	None
Mechanical ventilation / air renewal	Yes
Domestic Hot Water	The production of hot water is satisfied 100% by renewable energy. See next section.
Artificial lighting	Yes
Control and energy management	-

Figure 183: View of circulation pumps of chilled water [3]

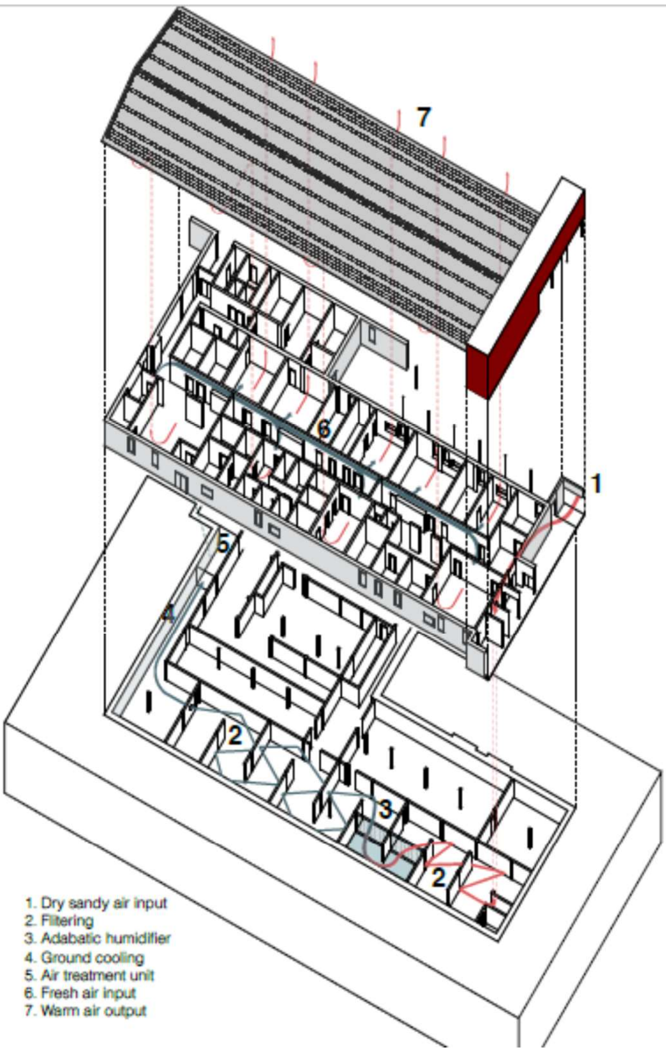

Figure 184: Principle of the cooling and filtering technological solutions

RENEWABLE ENERGY	
PV	None
Solar thermal	A solar farm, which contains 288 solar collecting items, powers the water-cooling system Surface: 1000 m^2 of solar panels Total power: 3 600 kW
Wind	None
Geothermal	None
Biomass	None

Figure 185: A solar farm of 1000 m^2 powers the water-heating system. [3]

BUILDING ANALYSIS AND KEY PERFORMANCE INDICATORS	
Thermal comfort indicators	1. Percentage of time outside an operative temperature range (Adaptive) : N/A
	2. Percentage of time outside an operative temperature range (Fanger) : N/A
	3. Degree-hours (Adaptive) : N/A
	4. Degree-hours (Fanger) : N/A
	5. Percentage of time inside the Givoni comfort zone of 1m/s: N/A
	6. Percentage of time inside the Givoni comfort zone of 0m/s: N/A
	7. Number of hours within a certain temperature range : N/A
Energy performance indicators	1. Energy needs for heating: - [kWh/m^2/year] : N/A
	2. Energy needs for cooling: - [kWh/m^2/year]: : N/A
	3. Energy use for lighting: - [kWh/m^2/year]: : N/A
	4. Energy needs for sanitary hot water: - [kWh/m^2/year]: : N/A
	5. Total Primary energy use: - [kWh/m^2/year]: N/A
	6. Renewable Primary energy generated on-site: - [kWh/m^2/year] : N/A
	7. Renewable Primary energy generated on-site and self-consumed: - [kWh/m^2/year]
	8. Renewable Primary energy exported to the grid: - [kWh/m^2/year] : : N/A

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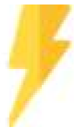
	9. Ratio of renewable primary energy over the total primary energy use (with and without compensation): - %
	10. Delivered energy (from electricity bills) : - [kWh/m^2/year]
Acoustic comfort indicators	1. Airborne sound insulation
	2. Equivalent continuous sound Level
	3. HVAC noise level
	4. Reverberation time
	5. Masking/barriers
Visual comfort indicators	1. Light level (illuminance)
	2. Useful Daylight Illuminance (UDI)
	3. Glare control
	4. Quality view
	5. Zoning control
Indoor Air Quality indicators	1. Organic compound
	2. VOCs
	3. Inorganic gases
	4. Particulates (filtration)
	5. Minimum outdoor air provision
	6. Moisture (humidity, leaks)
	7. Hazard material
Users' feedback	-

LESSONS LEARNED AND RECOMMENDATIONS	
Lessons learned & Recommendations	Temperatures often exceed 40°C in Sudan for long periods of time, often reaching and exceeding 50°C. It is this aspect of the Sudanese climate together with the presence of fine dust generated by the strong desert winds that has led to an in-depth study of the right type of insulation, cooling and filtering technologies. These technologies allow to reduce the energy consumption levels of the hospital while at the same time guaranteeing maximum levels of comfort [3]. The technological solutions that were sought were context-specific. In a country with very low levels of technology and with harsh climate conditions, the key features of the work were simplicity and innovativeness. Contrary to the practice of providing “third world” structures for “third world” countries, it was thus possible to prove that with innovation and low-cost technology we can guarantee the same standards of efficient health care as in any other Western health care centre [3].

BUILDING STRENGTHS AND WEAKNESSES

Strengths

		
Passive Design	**Energy Efficiency**	**Renewable Energy**

Weaknesses

1. It could have been an interesting project more related with the near Nile river, useful for cooling effect and mobility issues.
2. There is a thermal solar farm of 1000 sqm, used more efficiently to cool the large quantities of air needed for the entire building. However, the solar plant is not on the roof but on the floor and it occupies a green free area.
3. No reused/recycled materials were integrated in the design.

REFERENCES

[1] https://www.akdn.org/architecture/project/salam-cardiac-surgery-centre

[2] https://www.e-architect.com/africa/salam-centre-sudan

[3] https://www.archdaily.com/19061/salam-centre-for-cardiac-surgery-studio-tam-associati

[4] « Bioclimatic chart for the climate of Marrakesh ». [En ligne]. Disponible sur: http://climate.onebuilding.org/WMO_Region_1_Africa/MAR_Morocco/MS_Marrakech-Safi/MAR_MS_Marrakesh-Menara.AP.602300_TMYx.2004-2018.zip

[5] « Climate Consultant », Software Informer. https://climate-consultant.informer.com/6.0/ (consulté le nov. 03, 2021).

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