User-Centred Design of a digital twin for Energy performance in building: The case of a Hospital Building.

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Adjusting the performance of a building to reduce its energy consumption can be difficult when it concerns a hospital. Indeed, hospital buildings are in use 24 hours a day, 7 days a week. Among the largest infrastructures that consume energy, hospitals are one of the most important by combining different systems to ensure a high level of energy efficiency. These systems must address the sensitive load requirements and occupant experience. Thus, there are many parameters for optimizing energy consumption. Decision-makers use these parameters in their tasks to achieve objectives (i.e., reduce cost, reduce Co2 emission, reduce risk) depending on their profiles. These parameters affect decision-makers' everyday work and it's an issue for reducing energy consumption. The consequence is that hospitals need an energy management tool to overcome this issue. This tool makes it possible to plan and control energy consumption to improve energy-related tasks. Additionally, simulation tools can help decision-makers assess the energy performance of hospitals and select renovation plans. The process involves examining scenarios and determining the best action to achieve decision-makers' objectives to reduce energy consumption. So, there is a need to involve decision-makers (e.g., managers, public health officials, maintenance technicians, etc.) to facilitate the selection of solutions by considering multiple factors related to building performance and different decision-makers.

The Hospital SUDOE 4.0 project selected an expert system as a Digital Twin to develop an energy management tool. The digital twin is a new concept that virtually represents a real hospital building. In this sense, a bidirectional relationship between a real hospital and its virtual twin enables real-time visual management, prediction, and intelligent diagnosis to improve the real building energy consumption. Often, the design of these expert systems is a computer system emulating the decision-making ability of an expert, forgetting other decision-makers (hospital users, etc.) who play a vital role. Thus, Digital Twin, designed as an energy management tool, should support the decision-makers' energy-related tasks from one side, also support realistic renovation scenarios based on numerical simulations. For this reason, a decision support system (DSS) model based on multi-objective decision-making approaches is proposed. The DSS model enables the Decision-makers to browse solutions space by changing the selection of different objectives or alternatives concerning their tasks and profiles. To do so, we aim to understand the behaviour of the decision-makers in the actual situation to develop a User-Centred Design approach. For this, a mixed ethnographic method carried out in-depth observations of different behaviours of each group of decision-makers. The data collected analysis provides information for design model solutions (constraints, preferences, variables, etc.). Therefore, the Design space construction method was selected to generate an exploration space. This exploration space will merge the decision-makers, objectives, and alternatives. Thus, there will be many solutions. Here, a multi-objective optimisation surrogate model was selected based on the evolutionary algorithms. This model performs on multiple variables to generate Pareto optimum solutions. Then, the user interface of the digital twin allows the real-time exploration of the solution space for decision-maker selection regarding their profiles and tasks objectives.

Keywords: Digital Twin; Energy performance; User-Centred Design; Design engineering; Optimisation; Multi Objective Decision analysis; Ethnography.