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"A performance based management system for cost prediction suitable for school building stock"

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Abstract

The national existing school heritage is wide and varies significantly (e.g. morphology, age, construction, capacity, etc.) and many initiatives are ongoing to improve its safety, energy and functional situation. In a case study research the Municipality of Seregno has been adopted as sample municipality to analyze data collection and processing procedures with the aim to highlight the critical points and to develop and configure a management system able to bridge them. The research starts from the analysis of the energy performance of the school buildings pointing out the main needs and weaknesses. The following step is the tracking of the management procedures and data organization introduced to define a structure of the information able to support the new management system. Thus, a description and application of KPI helps to provide clear and data driven strategies for the improvement of the management system enabling a cost reduction. Finally, a proposed new energy management system, to be implemented within the Municipality procedures, defines a database, crucial to collect all the information about different properties and the energy audit procedures to gather and analyze the heating costs. The system is tested and discussed and furthermore allows to provide an energy predictive model for energy costs suitable for the Municipality to support a reliable resources plan.

1. Introduction

In Italy the school buildings stock is made of more than 62,000 building units and 35% of these buildings are in need of maintenance and refurbishment to achieve the required levels of environmental well-being, health, attractiveness and cost-effectiveness (MIUR, 2013). A survey (Legambiente, 2015) on 96 municipality owning approximately 10% of the whole school building stock pointed out that school buildings are old: only 9.3% of the surveyed buildings had been built between 1991 and 2014; 65% before 1974, hence before Laws 373/1976 (energy demands control) and 64/1974 (seismic performance of structures). The same research highlighted also significant difference in school buildings condition according to their location: approximately 50% of the building stock in the South of Italy need urgent maintenance operation or refurbishment while in the North the percentage decreases to around 33%. Despite the poor condition of school buildings, the few maintenance operations done in the past years had been aimed to a technology and safety upgrade of thermal and electric plants to comply with new safety regulations (Desideri et al., 2002). Nowadays the economic situation in Italy urges public clients to optimize their asset management processes and to adopt a lean approach with a continuous adaptation and balance of the building energy behavior to address variable conditions (e.g. climate change, regulation restriction, changing properties of the materials during the lifespan, energy cost and incentive programs, etc.). In this scenario, it is central for the public administrations to adopt a management system able to optimize the resources' use. The core issue for the existing building heritage management is the total lack of an information system to collect, accommodate and organize data for the different buildings and of an efficient management system for the energy consumption. Starting from this situation, the research focuses on school buildings data collection and processing procedures of the Municipality of Seregno with the aim to highlight the critical points and to develop and configure an asset management system able to bridge them. The urgency of is strictly related to the data shown in Fig. 1 where the amount of money spent by the Municipality for energy, water and maintenance in the last years is plotted. Asset Management (AM) is one of the core activities of a Municipality, it allows to realize value from an asset in the achievement of Municipality's objectives. Among these the following benefits of asset management (ISO 55000) can be found:

- Improved financial performance: improving the return on investment and reducing costs can be achieved, while preserving asset value without sacrificing the short term or long-term realization of Municipality's objectives;
- Informed asset investment decision: enabling the Municipality to improve its decision making and effectively balance costs, risks, opportunities and performance;

- Demonstrated social responsibility: improving the Municipality's ability to, for example, reduce emissions, conserve resources and adapt to climate change, enables it to demonstrate socially responsible.

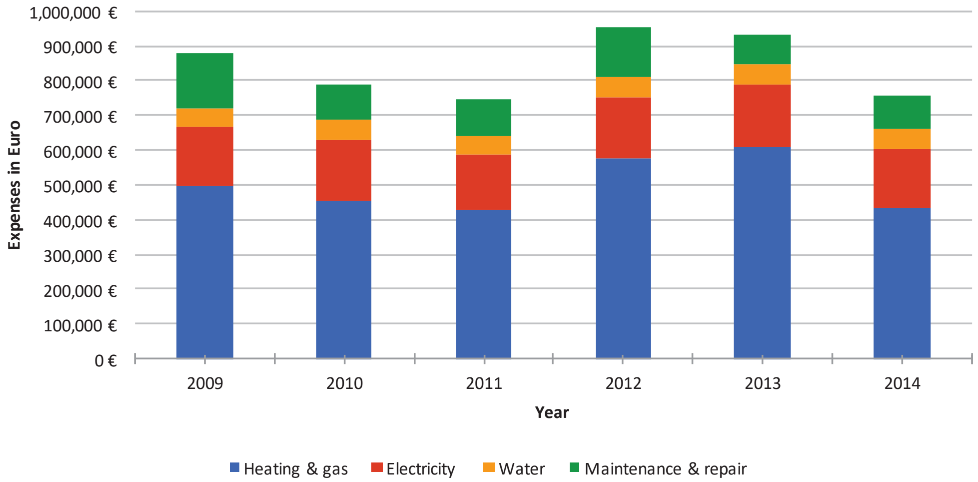

Fig. 1: School building stock expenditure in Seregno Municipality (capitalized to 2014)

Moreover, many studies show that a comfortable and well managed schools can positively affect the quality of education and pupils' understanding skills (Issa et al., 2011). In fact, learning performances can be greatly enhanced if indoor conditions and school spaces are improved, studies show an improvement from an average value of 16% to a maximum of 50% if ventilation (Building Bulletin BB90, Building Bulletin BB 93, Building Bulletin BB101), lighting and solar loads (Chatzidiakou et al., 2014) are taken into account when design air treatment. Besides, if reducing energy demand is the main purpose of the Municipality, significant results can be achieved not only undertaking retrofit measures on buildings, but also by promoting more conscious attitudes on the part of users, a research (ENEA, 2012) estimated they can reduce their current energy consumption by 20%. Conversely, energy retrofit on existing school buildings, while significantly reducing fuel consumption, generates additional costs of considerable magnitude. In these cases, the payback period may be too long to invest in the retrofit. A wider research not limited to school buildings (Kumbaroğlu et al., 2012), as instance, indicates that energy price changes significantly affect the profitability of retrofit investments, and that high price volatility creates a substantial value of waiting, making it more rational to postpone the investment. Furthermore, since schools are public buildings that host a large number of users throughout their lifecycle, it is appropriate to strengthen maintenance strategies, especially in relation to the fact that often the weakness or lack thereof can cause tragic consequences. The case study research method used in this study is recognized (Yin, 1984) as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used. Case study research excels at bringing us to an understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research.

2. School Buildings data analysis

Every information about Seregno's eleven school buildings are stored in paper documents archived in folders in different offices of the Municipality. Thus, the first step of the research had been to collect all folders in a single data room and to dig into them to find useful information to be stored in a database. Unfortunately, data were not available for all the schools so some analyses had been limited to a subset of schools.
In order to compare energy, use and maintenance costs of buildings researchers (Pérez-Lombard et al., 2008) started from a breakdown of buildings' surface according to its use. Fig. 2 shows the use of surface in each school according to 5 categories: Classes & offices; Bathrooms and canteen; Gym & auditorium; Corridors & passageways; Storage & technical rooms. This classification is based on a breakdown of school spaces made using Uniclass 2015 as classification system. Uniclass 2015 is a unified classification for the industry covering all construction sectors, it contains consistent tables classifying items of all scale from a facility down through to products.

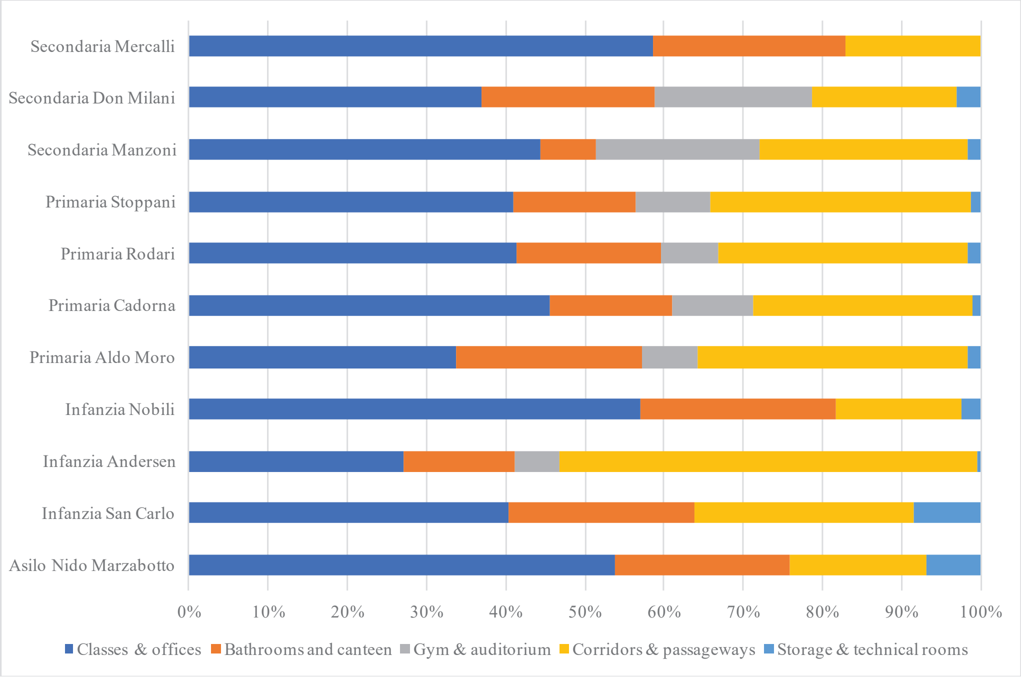

Fig. 2: Space uses in the eleven schools investigated

The so chosen 5 categories were used to compare the effectiveness of space usage (Fig. 3) finding out that there is a huge difference among the schools. If the analysis is focused only on the surface of the classrooms, the school with the highest ratio between surface (m^2) and number of students has 46% more space per student than the mean and the one with the lower ratio -37% than the mean. If the analysis is widened to the whole surface of the schools, the difference from the mean is even bigger spanning from -35% to +74%. Noteworthy, the mean size of the schools in Seregno is around 3.150 m^2, more than the double of the Italian mean as in 2015 XVI Legambiente Report. Focusing the study on Expenses related to energy costs, the emphasis should be on electricity costs and on expenses made for either gas or district heating, since some of the schools during the period of analysis (from 2009 to 2014) dispose of their heating system and connect to a central heat generator using gas only for kitchen where a canteen is available. Moreover, to compare schools with different use (first grade, second grade, with a gymnasium or without, with a canteen or without, …) expenses were divided by the "teaching surface" of the school, i.e. the surface of all the spaces directly or indirectly connected to teaching. As instance, classrooms and offices for teaching staff were computed in the "teaching surface" while the area of canteen or gymnasium were not. Given the mean size of the schools in Seregno it is not unexpected the first result of this analysis: the average of the total surface dedicated to class activities of all the school in the Municipality is much higher than the Italian average. Fig. 4 summarizes the results of the analyses on costs related to electricity supply. In the picture can be seen that there are huge differences among the schools in terms of efficiency when electric demand is taken into account. Comparing small size schools ("Stoppani", "Nobili" and "Andersen" have almost the same "teaching surface"), school named "Andersen" has much lower expenses than "Nobili". Notably, "Andersen" has a mean electricity cost 61% lower than "Nobili" even if they are both kindergarten and have almost the same number of students.

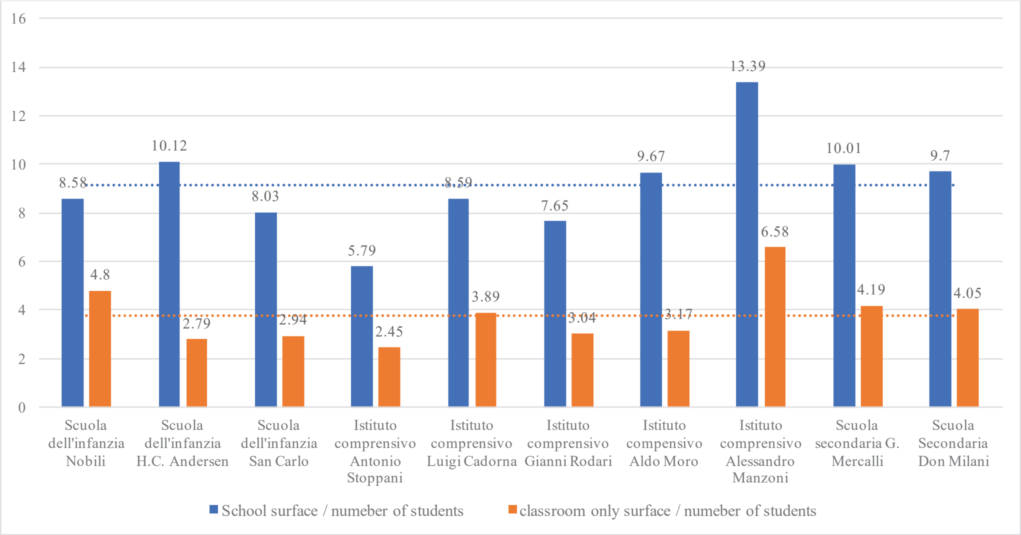

Fig. 3 Ratio between school surface (m^2) and number of students for the schools in Seregno (the dotted line is the mean)

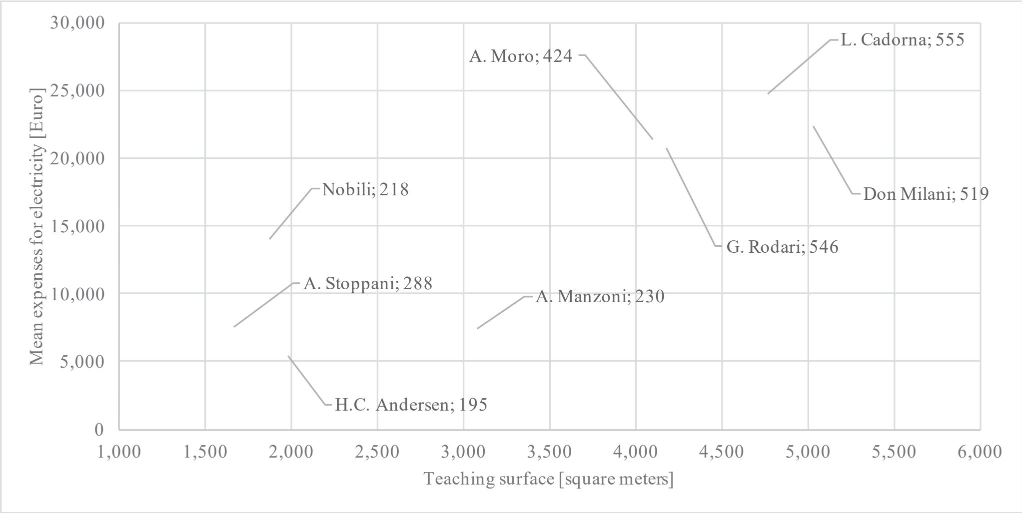

Fig. 4 Expenses for electricity (mean of five years capitalized to 2014) according to the surface dedicated to teaching activities for each school. The surface of each circle is proportional to the average number of students (shown besides the school name in the graph)

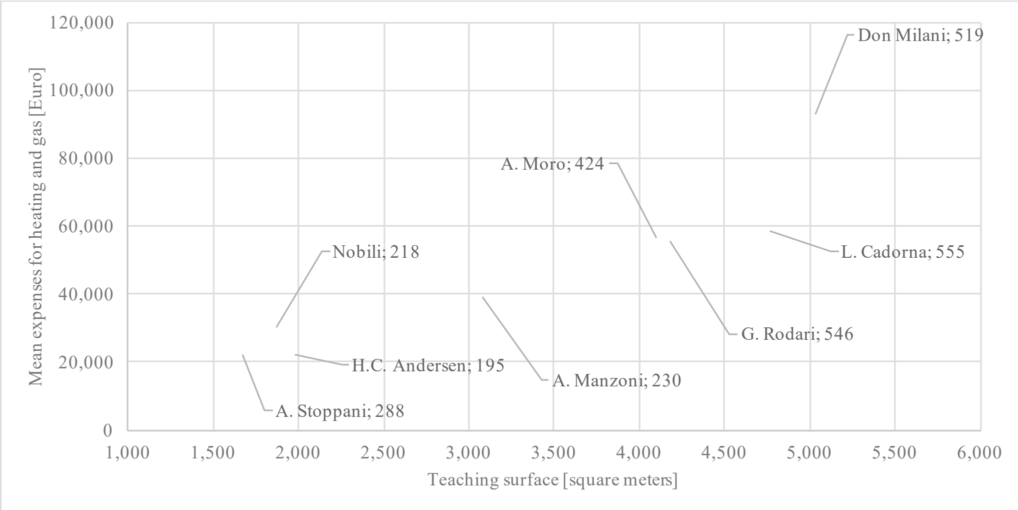

Fig. 5 Expenses for heating and gas (mean of five years capitalized to 2014) according to the surface dedicated to teaching activities for each school. The surface of each circle is proportional to the average number of students (shown besides the school name in the graph)

On the other side, analyzing big schools ("Don Milani", "Cadorna" and "Rodari" have almost the same number of students and the size, at least of the first and the second, are quite close) Fig. 4 shows that the expenses for this kind of schools are more related to the number of students than to the "teaching surface". Fig. 5 depicts the results of the analysis on heating and gas expenses during the years from 2009 to 2014 (all expenses capitalized to 2014). Focusing again on the same three big schools, it's worthwhile to notice that "Don Milani" has almost the same "teaching surface" of "Cadorna" and roughly the same number of students but consume much more energy (59% more than the energy costs of "Cadorna" school). The difference can partly be caused by the amount of surface not used for teaching, as instance "Don Milani" has a bigger gymnasium, but most of the difference is due to worst insulation and system efficiency. Among the school that host a large number of students, "Rodari" and "Moro" have almost the same surface and energy costs but the latter has something like one hundred students less than the former. If the focus is moved to small school, "Stoppani" is the smallest but most efficient, hosting at least seventy students more than the others but consuming almost the same in terms of heating and gas costs. Even "Manzoni" seems quite efficient because it has similar costs as the other three small schools but has a much bigger "teaching surface". An analysis on the maintenance costs gave almost the same results as the one on heating and gas, with the exception of "Rodari" whose expenses for maintenance are almost 74% more than the average of the school in Seregno.

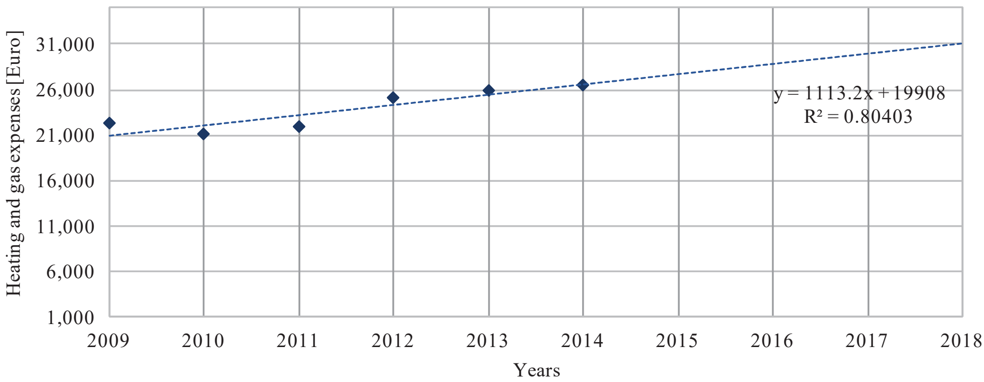

Fig. 6 Example of predictive model for energy costs (school "Rodari")

All the data acquired and elaborated had been used to implement predictive models for future expenses (Heating & gas, Electricity, Maintenance) so as to solve one of the main Municipality's problem, the reliability of costs forecast. This is a very sensitive problem for a Municipality because they are allowed to spend only the money they had budgeted in a specific document ("programma biennale degli acquisti di beni e servizi" or "programma triennale dei lavori pubblici" according to art.21 D.Lgs. 50/2016). Fig. 6 shows, for example, the linear model to be used to predict heating and gas expenses for school "Rodari". Models like this one are available to the municipality for each school and for all the three types of expenses.

3. Concluding remarks on the management system

The analysis on how expenses for schools were managed in the Municipality of Seregno pointed out a main lack: there was no management system. Expenses were forecast without an exact knowledge of how much was spent the previous year, no records were taken on who did what and how much was paid for maintenance operation except for paper documents that were collected, stored and never used anymore.

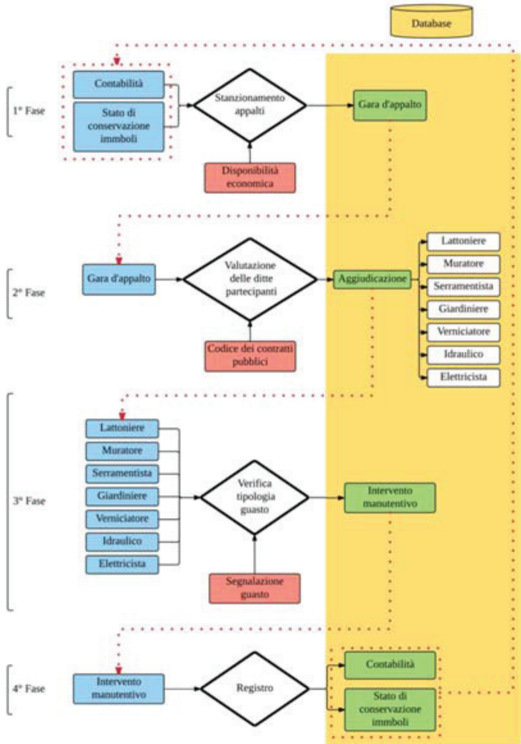

Fig. 7 New workflow for maintenance works

To improve this unbearable situation new procedures were studied first and implemented then (Fig. 7 shows the new workflow in use in Seregno). Besides all the new procedures, it has to be pointed out that the most important element is the new databased implemented to collect all data received as feedback from every maintenance operation and from the energy providers (both electricity and district heating or gas). This database will allow for better costs forecast, the most urgent among the problems the Municipality has, but will also be the pillar of new and innovative use, operation and maintenance strategies for school buildings in Seregno.

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