SUSTAINABILITY LEVEL OF AN ACADEMIC BUILDING

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Abstract. *The capability to identify the sustainable essential aspects is the key factor to support a sustainable construction assessment. An evaluation methodology to show the possibility of the buildings to ensure and develop its sustainability capacities and to recognise and certify construction sustainable practices implemented is the main scope of this research. Several countries have developed their own tools for the sustainability assessment of the building stock. Presently there are several tools that can be applied to assess the construction sustainability during the design execution or the operation phase of buildings. In Portugal was developed the LiderA, an assessment and voluntary acknowledgement system for sustainable building and built environment. Is composed of construction environmental performance levels from the point of view of sustainability, which can be compared with different performance levels, A to E. The aim of this paper is to present the results of the sustainability assessment of an academic building, applying the LiderA system. The sustainable assessment is focused in the operation phase of the building and a sustainability label was obtained. During the assessment the principal problems detected in the building are related with the energy efficiency, the indoor thermal comfort, air quality, and lightning, water and environmental management. Accordingly sustainable improvement measures are also appointed to reach a higher sustainability level and an economic analysis of its implementation was made.*

Keywords: *sustainability level, academic building, economic analysis*.

1. Introduction

Awareness in regard to climate change, the destruction of the ozone layer and the scarcity of natural resources, led to a growing concern about the consequences of human activities on the environment. It is recognised that the construction industry is responsible for a large part of waste production and its landfill deposit, as a result of their activities, mainte-

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nance and use of buildings [1]. According to results exposed by the General Service of Energy (DGE) in 2000, buildings (housings and services) in Portugal are, in use phase, responsible for the consumption of about 20% of the energy resources (39.3% in 2007 [2]), for 6.7% of water consumption and the annual production of 420 million cubic metres of wastewater. According to the National Statistics Institute (INE), the construction industry is responsible yearly for the production of about 7.5 million tonnes of solid waste. The aim of the construction industry is to obtain a product/building that complies with the requirements, the economic interests of the owner, guarantees safety conditions, under the effect of natural and human actions, presents durability characteristics, reducing the deterioration throughout its lifecycle and finally that contributes with the smallest environmental impact. Only with the balance between these aspects this sector will be able to comply with the human needs of present and future [3]. The aim of this paper is to present the results of the sustainability assessment of the Civil Engineering Department of the University of Aveiro, applying the LiderA – Sustainability Assessment System. LiderA, the acronym for Leadership for the Environment in Sustainable Building, is an assessment and voluntary acknowledgement system for sustainable building and built environment [4].

2. Sustainability

2.1. Sustainable Construction

The term “sustainable construction” was firstly proposed by Kibbert [5] to describe the responsibilities of the construction concerning the concept and objectives of sustainability. According to Kibbert [5], the existing knowledge and the diagnosis of the construction industry, in terms of environmental impacts, show that there is a need for changes to achieve sustainability objectives. The United States Green Building Council [6], recognize that a good environmental performance is characterized by having reduced, or even resolved, the negative environmental impacts on the environment and for the building users. So, the building sustainability assessment can be carried out according to sustainable management principles of constructed area, water economy and efficiency criteria, energy efficiency and renewable energy appliance, conservation of materials and resources and indoor environmental air quality [7]. Another approach, the program *Brown is Green* from the Brown University, considers that an environmentally responsible construction has to reduce impacts during the constructive processes and its expected serviceability period. Good environmental performance indicators include the reduction of energy consumption in heating, cooling and lighting systems and also the selection of non-toxic and recycled materials and components [7].

The ability to identify the essential aspects of sustainability is a key factor to base the assessment of sustainable construction, as well identifying, and acknowledging certified sustainable construction practices [8]. The sustainability assessment purpose is to gather data and report information to serve as a basis for decision-making, during the different phases of a building lifecycle. Nowadays there are several tools that can be applied in the construction sustainability assessment during the design, the execution or the operation phase of the buildings [7,10,11,12]: VisualDOE, Design Builder (EnergyPlus), SimaPro, BEES, ATHENA, LISA, Performance Based Buildings, NABERS, LEED, BREEAM, CEEQUAL, LiderA, SBTool. Several countries have developed their own assessment tools for sustainable buildings and built environment, adapted to their legal, social, economic and environmental requirements.

LiderA – Sustainability Assessment System is a Portuguese registered brand defines a growing scale of construction environmental performance levels – A to E – from the point of view of sustainability, which should be better than existing practices (level E). If the verified LiderA performance reaches a final assessment of the sustainability labelled as class C, B, A, A+ or A++, buildings or built environments are certified with the correspondent sustainability level [4].

2.2. Assessment system

The LiderA system has three levels of application: strategic, design and lifecycle management (operational). It focuses on environmental assessment of a building, where the environmental performance is evaluated according to a group of criteria, and is divided into three main components: the declaration of a set of performance criteria (the structure); the assignment of possible scores for each performance criteria through the performance levels achieved (evaluation); the demonstration mode of the final environmental performance (the result). This system uses the definition of evaluation criteria according to which the performance of the building is verified. Each criteria performance is measured according to an evaluation scale. The sustainable degree is measurable and the building can attain a certificate if achieved a performance level of C, B, A, A+ or A++.

The system criteria define singular aspects according to which the performance of the building is evaluated [4, 13, 14, 15].

2.3. Areas and criteria

The LiderA system evaluates areas and criteria to measure the sustainability level. The legal requirement defined by national codes and laws defines the minimal essential requirements that have to be verified in the different evaluated areas. Their increases constitute the sustainability achievement [4, 14, 15].

The method evaluates 6 areas that include 22 specific aspects of intervention and 43 assessment criteria. These areas include the site and integration, the resources consumption efficiency, the socio-economic adaptability, the environmental management and innovation, the environmental load impacts and environmental comfort. The most relevant aspect in the assessment is the resources consumption efficiency which is attributed a relative importance (weight) of 32 % (see Figure 1).

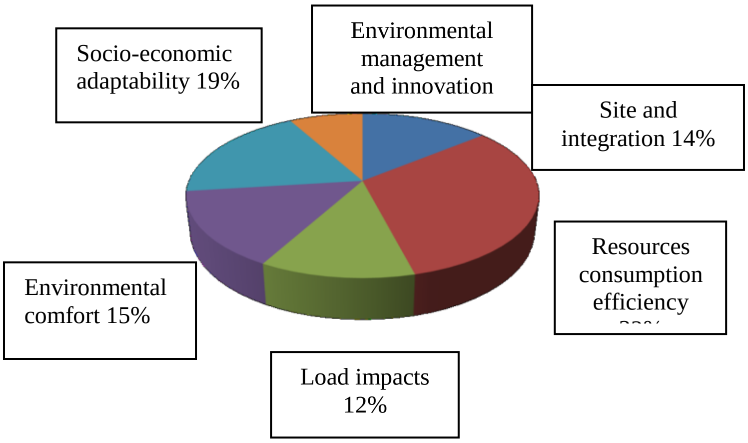

Figure 1. Areas weight LiderA 2.0 [4].

3. Case study

3.1. Building assessment by LiderA

The Civil Engineering Department is located in the University Campus of Santiago, in the city of Aveiro located in the centre of Portugal. It was constructed from 2004 to 2006. The building has 3 floors and 1 underground floor. As the building is in use its assessment was carried out for the exploration phase.

Figure 2. Civil Engineering Department.

Regarding site and integration (see Table 1) this building is part of the University Campus of Santiago of the University of Aveiro, situated next to the Salinas of Aveiro. This Campus is characterized by buildings with three floors, with external fired clay brickwork, as the building under assessment. So, it is considered integrated with its surrounding (*C*5), its construction respect the Urban Frame Plan (*C*1), however it does not provide a significant interconnection of habitats (*C*4) due to the fairly small free area of soil (*C*2) which fragments the interconnection of habitats.

Table 1
Site and integration assessment

A++	A+	A	B	C	D	E	F	G	
									Area: Soil
						🟧	🟧	🟧	C1: Territorial valorisation
						🟧	🟧	🟧	C2: Environmental location optimization
									Area: Natural ecosystems
						🟧	🟧	🟧	C3: Ecologic valorisation
						🟧	🟧	🟧	C4: Habitats interconnection
									Area: Landscape and heritage
			🟩	🟩	🟩	🟩	🟩	🟩	C5: Local landscape integration
						🟧	🟧	🟧	C6: Protection and enhancement of heritage

In terms of consumption of resources (see Table 2) the lack of solar passive measures implemented lead a low passive performance of the building (C8). There is also a lack of renewable energy sources, or energy-efficient equipments, which does not allow the reduction of the level of CO_2 emissions for the criteria of carbon intensity (C9). However, there is in the 2^{nd} floor corridor, bathrooms, lighting systems with motion sensors. As the building was constructed before the implementation of the EPBD – Energy Performance Building Directive it was not assigned an energy certification (C7). Relatively to the consumption of drinking water (C10), the building is supplied by the public water supply network and is equipped with temporized taps to control users' consumption. However, these devices cannot be classified as hydro efficient. On the management of local waters (C11) there are no measures implemented. Regarding materials, this building is characterized by good durability (C12) constituted by a metal frame with protection against fire, concrete floors and external brickwork. So, the expected service life of this structure is 100 years, for the finishing devices is about 10 years and to the installed equipment and services devices is about 30 years. The materials used were mostly produced at long distance from the construction, concrete and bricks that represent 12.5% of all the materials used were produced at a distance less than 100 km (C13). No materials have environmental certification (low impact), or are recycle or renewal. In spite of this it was not included other materials (with dangerous substances: asbestos, benzene, lead, PCB, chromium, chlorates etc.) (C14).

Regarding environmental loads (see Table 3) the sewage systems are discharged into public drainage systems and are treated in a central residual water treatment facility (C16), but there is no recycled water system (C17). About particles and acidic substances (C18), it is forbidden to smoke inside the building and there is only one combustion equipment (a gas heating boiler). There are no measures implemented to reduce the production of solid waste but its selective separation is made to be recycled (C20). In the sequence of office activities the print cartridges are considered as dangerous waste (C20) and are separated for adequate recycling. About the production of airborne noise (C22) the equipments are very silent and the sound insulation solutions used are considered adequate and comply with the codes. The external light-thermal pollution (C23) is minimal because there are only external lighting systems and there are no dark zones and all the car parking is outside the area of the building. Surrounding the building are green areas, clear pavements and a natural lagoon area and small water surfaces.

Table 2

Resources consumption efficiency assessment

A++	A+	A	B	C	D	E	F	G	
									Area: Energy
						🟧	🟧	🟧	C7: Energy certification
						🟧	🟧	🟧	C8: Passive performance
						🟧	🟧	🟧	C9: Carbon intensity
									Area: Water
						🟧	🟧	🟧	C10: Drink water consumption
						🟧	🟧	🟧	C11: Local water management
									Area: Materials
				🟩	🟩	🟩	🟩	🟩	C12: Durability
					🟨	🟨	🟨	🟨	C13: Local materials
						🟧	🟧	🟧	C14: Low impact materials
									Area: Food
							🟧	🟧	C15: Local production of food

Table 3

Environmental load impacts assessment

A++	A+	A	B	C	D	E	F	G	
									Area: Residual water
						🟧	🟧	🟧	C16: Residual water treatment type
						🟧	🟧	🟧	C17: Residual water flow rate reuse
			🟩	🟩	🟩	🟩	🟩	🟩	C18: Particles and/or acidic substances
									Area: Waste
						🟧	🟧	🟧	C19: Waste production
				🟩	🟩	🟩	🟩	🟩	C20: Dangerous waste management
				🟩	🟩	🟩	🟩	🟩	C21: Waste recycling
									Area: Exterior noise
			🟩	🟩	🟩	🟩	🟩	🟩	C22: Noise to the exterior
									Area: Light-thermal pollution
				🟩	🟩	🟩	🟩	🟩	C23: Thermal and lighting effects

Considering the indoor comfort (see Table 4 and 5) in respect to ground level of the building, it presents different types of function, therefore different thermal requirements and characteristics. The ground floor (see Table 4) has a mechanical ventilation system (main entrance, corridor and laboratory). There are no materials that have volatile organic compounds (VOC) (C24). In relation to thermal comfort (C25) it is considered cold during the winter and fresh during summer by the effective users (teachers and students). The internal compartments have low level of natural lighting (C26) leading to the permanent need of artificial lighting. The noise insulation levels for airborne and stepping sounds are satisfactory. Each compartment is equipped with different equipments according to the requirements: extraction and insufflations axial ventilators in the laboratory, the laboratory offices are connected to the air treatment unit, and have heating radiators connected with the central heating system and air vents.

In the first floor (see Table 4) the classrooms have no natural direct lighting and no direct contact with the exterior ventilation (after the conclusion of this work in each classroom an opaque wall was substituted by a glass wall with a window that can be open). It is always necessary its artificial lighting and ventilation. They are considered cool in winter and hot during the summer, and they are equipped with central air conditioning.

In the second floor (see Table 5) all the classrooms and offices have good natural lighting and reasonable natural ventilation (window opening). However, the compartments with large glazed areas lead to thermal and acoustic discomfort (due to the insufficient thermal and acoustic insulation of the external envelope). The surrounding of the building has large green areas that contribute to a best exterior air quality feeds.

Table 4

Environmental comfort assessment of the ground and first floor

A++	A+	A	B	C	D	E	F	G	
									Area: Air quality
						🟧	🟧	🟧	C24: Air quality level
									Area: Thermal comfort
						🟧	🟧	🟧	C25: Thermal comfort
									Area: Lightening and acoustic
						🟧	🟧	🟧	C26:lighting levels
						🟧	🟧	🟧	C27: Acoustic insulation / acoustic levels

Table 5

Environmental comfort assessment of the second floor

A++	A+	A	B	C	D	E	F	G	
									Area: Air quality
				🟩	🟩	🟩	🟩	🟩	C24: Quality air levels
									Area: Thermal comfort
					🟨	🟨	🟨	🟨	C25: Thermal comfort
									Area: Lighting and acoustic
				🟩	🟩	🟩	🟩	🟩	C26:lighting levels
						🟧	🟧	🟧	C27: Acoustic insulation / acoustic levels

Regarding social and economical experiences (see Table 6) the building is 500 meters far from a main public bus stop and 1 km distance from the railway station (C28). Its surroundings are equipped with wide sidewalks and bike circuits (C29). The building is equipped with all the means needed for handicapped users (access ramps, elevators, adapted WC) (C30). Concerning life cycle cost (C40) the equipment choice did not contemplate its energy efficiency; however they have a good quality-price binomial nevertheless needing periodic maintenance. The majority of the interior partition is in plasterboard and the interior distribution of space is considered well defined, allowing easy reorganization of the interior space, giving interior flexibility and adaptability (C31).

There is also easy access to the technical pipes and building equipment. This is a public building with economic activity, through intellectual production and external services to private enterprises and public institutions, city and town councils, having some local economic dynamic impact (C32). It generates local work because of its activity and integration into the University Campus (C33). About local amenities (C34) the building is implanted in the University Campus near the natural area of the *Aveiro Ria*, with large green areas and lagoons. Inside the Campus there are canteens, cafeterias, a restaurant, a self-service restaurant, bank, kindergarten, medical services, bookshop, photocopies centre, travel agency, etc. Near the Campus is localized the central Hospital, schools, a swimming pool, restaurants, the City Park, etc. The several green areas assure the accessibility and interrelation of the building with the community (C36). About the internal comfort control only some of the compartments have devices that permit the control by the users of temperature, ventilation and natural lighting. During the design phase were implemented structural solutions against the seismic actions, winds and high soil water level. Resistant and durable materials were used according with the weather, human and occasional actions (C38). Concerning the intrusion (C39) the building has video surveillance and is under the security of the Campus.

Table 6

Socio-economic adaptability assessment

A++	A+	A	B	C	D	E	F	G	
									Area: Access to everyone
					🟨	🟨	🟨	🟨	C28: Access to public transports
			🟩	🟩	🟩	🟩	🟩	🟩	C29: Low impact mobility
			🟩	🟩	🟩	🟩	🟩	🟩	C30: Access to everyone – inclusive solutions
									Area: Economic diversity
					🟨	🟨	🟨	🟨	C31: Flexibility / Adaptability of uses
					🟨	🟨	🟨	🟨	C32: Local economic dynamic
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	C33: Local work
									Area: Amenities and social interrelation
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	C34:local amenities
				🟩	🟩	🟩	🟩	🟩	C35: Accessibility and interrelation
									Area: Participation and control
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	C36: Control capacity
						🟧	🟧	🟧	C37: Participation conditions and governance
			🟩	🟩	🟩	🟩	🟩	🟩	C38: natural risks control – Security
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	C39: Human threat control
									Area: Life cycle costs
					🟨	🟨	🟨	🟨	C40: Life cycle cost

Regarding the environmental and innovation management (see Table 7) of the building it was verified that the environmental conditions of use (C41) were not implemented: the users have not received information related with environmental aspects, equipment information etc. According with the environmental management (C42) the building has no environmental management system, as well as a manual of good practice, or innovation integrated solutions.

Table 7

Environmental management and innovation assessment

A ++	A+	A	B	C	D	E	F	G	
									Area: Environmental management
						🟨	🟨	🟨	C41: Environmental use conditions
						🟨	🟨	🟨	C42: **Environmental** management systems
									Area: Innovation
						🟨	🟨	🟨	C43: Innovation of practices, solutions and integrations

The global building classification was D, superior to the usual practice (E), but inferior to the classification that attribute a sustainability label recognized by the system. This recognition is only for classes from C to A.

3.2. Assessment with improvement measures

A set of improvement measures, according with its cost-benefit relationship, were chosen with the aim to achieve a sustainability level which can be certifiable by the LiderA system.

Regarding the site and integration (see Table 8) the use of building adjacent soil space for the creation of a green space, wooded and with native species, enables improvements in the level assigned to the area of natural ecosystems. This solution permits the percentage increase of green area of soil and seeks multiple ecological recovery interventions (C3) as well promoting the continuity with the surrounding areas favouring the interconnection with other habitats (C4). These two criteria will be classified with B and C as depicted in Table 8.

Table 8

Site and integration new assessment

A ++	A+	A	B	C	D	E	F	G	
									Area: Natural ecosystems
			🟩	🟩	🟩	🟩	🟩	🟩	C3: Ecologic valorisation
				🟩	🟩	🟩	🟩	🟩	C4: Habitats interconnection

In terms of consumption of resources if renewable energy sources to produce electric energy are implemented, efficient electric equipments adopted and external shading systems installed the lack of solar passive measures for the building (C8) will be reduced. The adoption of energy efficient equipment, with energy label higher than B, lead to the reduction of the CO_2 emissions for the criteria that evaluates carbon intensity (C9).

For drinking water consumption (C10) several solutions were indicated to reduce consumption (see Table 9): the installation of efficient water labelling devices, such as the use of flow reducers and dual discharge flushing cisterns; native species plantation in green areas; grey and rain water reusing for irrigation and floor washing; implementation of a monitoring system of water consumption. The reuse of rainwater leads to a higher local water management (C11).

Table 9

Resources consumption efficiency new assessment

A ++	A+	A	B	C	D	E	F	G	
									Area: Energy
					🟨	🟨	🟨	🟨	C8: Passive performance
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	C9: Carbon intensity
									Area: water
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	C10: Drink water consumption
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	C11: Local water management

C10:
Drink water
consumption

Regarding environmental charges (see Table 10) with the reuse of grey water the volume of residual water would be reduced and a better assessment class in respect to the residual water treatment is attained (C16) as well as in the reuse of grey water (C17). The implementation of a better and broader waste recycle system complemented with information and awareness of users will increase the waste recycle quantities (C21).

Table 10

Environmental load impacts new assessment

A ++	**A+**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	
									Area: Residual water
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	**C16: Residual water treatment type**
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	**C17: Residual water flow rate reuse**
									Area: Waste
			🟩	🟩	🟩	🟩	🟩	🟩	**C21: Waste recycling**

A building thermal simulation was made with the software EnergyPlus/DesignBuilder. Results demonstrate that the building has low energy efficiency revealing a large temperature variation for the indoor temperatures, evidencing insufficient envelope insulation and low thermal inertia. Energy consumption analysis depicts that the indoor energy gains are essentially obtained through the internal heating and by solar radiation through glazing. Second floor rooms oriented to Northeast (NE) and Southwest (SW), considered the most problematic, were simulated considering internal and external shading with lighting control systems. The study show insignificant improvement in the global thermal performance of the building but these rooms will certainly achieve a slight better internal comfort (C25) due to the decrease of the discomfort hours and the internal gains during summer. It would be necessary to reduce the external envelope glazing area to improve thermal comfort. For the others floors it is proposed an improvement of the artificial lighting (C26) in the classrooms (luminaries sectioning that allows the lighting control according the activities) and the implementation of local lighting lamps in the offices (see Table 11).

Table 11

Environmental comfort new assessment of the ground and first floor

A ++	A+	A	B	C	D	E	F	G	
									Area: Lightening and acoustic
					🟨	🟨	🟨	🟨	C26:lightening levels

Regarding the environmental management and innovation, if implemented environmental information (C41) like user and local building manager manuals, equipments users manuals, building consumption monitoring systems, periodical users information sessions, this will improve this criteria to level A. All this solutions will contribute to the building environmental system (C42) improving its assessment level relative to these aspects. The other systems like the use of renewal energy, flow water reducers, the reuse of grey and rain water constitute innovation practices (C43). Table 12 depicts the improvement of the assessment level of these criteria.

Table 12

Environmental management and innovation new assessment

A++	A+	A	B	C	D	E	F	G	
									Area: Environmental management
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	C41: Environmental use conditions
			🟩	🟩	🟩	🟩	🟩	🟩	C42: **Environmental** management systems
									Area: Innovation
		🟩	🟩	🟩	🟩	🟩	🟩	🟩	C43: Inovation of practices, solutions and integrations

With the implementation of the solutions described the building will achieve a global sustainable assessment of C, 25% higher than the common practice (level E). As the LiderA labelling is done from the class C to A this building would be recognized as sustainable.

3.3. Economic evaluation of the improvement measures

The economic evaluation of projects whose impacts cause a change in the quality of the environment, need to be assigned a monetary value to environmental goods and services, to be able to assess the feasibility of a project. In economic terms there are available several techniques for valuing environmental goods and services and assessing their impact on the economical value of these goods and services.

The approach to evaluate the improvement measures costs, in order to obtain a higher ranking through the LiderA assessment system in relation to the original building state (without improvements) was carried out using the method of net present value (NPV). This method is a financial technique that compares the discounted cash flows with the initial investment. The NPV is given by the expression:

$$NVP = \sum_{i=1}^{n} \frac{VF}{(1+K)^{i}} - I.I \qquad (1)$$

NPV, net present value of the money;
VF, future value of the money;
K, interest rate on investment or cost of capital;
I.I, initial investment.

In this case the revenues are correspondent to the cost of the energy and water savings obtained with the proposed improvement solutions. The return values will suffer an update that is due to the fact that the value of money is updated over time.

This value is achieved by applying a interest rate of 5% (*K*). Considering an increase of the energy cost by 2.5% per year, the value of the revenue will decrease of 2.5% annually.

This method allows estimating in how many years the investment is recovered. The investment is profitable when the value of NPV is greater than zero and not profitable when it is less than zero. For this study it was obtained a payback period of about 16 years.

4. Conclusions

During the sustainability assessment the worst evaluations were in respect to: energy, waste, indoor air quality, thermal comfort, indoor lightening, water and environmental management. During the study it was demonstrated that each one of these points can be improved in spite of the difficulties due to the building being in use. The improvement measures permit to achieve the recognition and the sustainability labelled as C through the Lider A assessment tool.

In the selection of the improvement measures, various constraints were identified because the building is already occupied and in use, which makes it impractical to adopt many of the solutions that would be needed to improve the environmental performance of the building and to achieve a better payback period.

In spite of the payback period do not be the best, the improvement measures contribute to improve the exterior and interior environmental conditions and consequently to a higher comfort of the users.

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