XVI International Conference on Durability of Building Materials and Components
DBMC 2023, China
K.F. Li and D.P. Fang (Eds)

Changes in Educational Buildings at Very Early Stages of Their Life Cycle

G. Cignachi[1], P. Gaspar[2] and H. Farias[1]

[1]CIAUD – Centro de Investigação em Arquitetura, Urbanismo e Design, Lisbon School of Architecture, Universidade de Lisboa, Lisbon, Portugal, grasielacignachi@gmail.com (First Coauthor); hfarias@fa.ulisboa.pt (Third Coauthor)
[2]Lisbon School of Architecture, Universidade de Lisboa, Lisbon, Portugal, plgaspar@fa.ulisboa.pt

Abstract. *Changes always occur in buildings at any stage of their life cycle. In this paper, particular attention is paid to changes that occur very early on this process, sometimes between bidding and very initial construction stages, in the context of public procurement and building. The research is based on the total building stock of the Federal Institute Sul-rio-grandense, in Brazil, which holds presently 14 campuses and more than 120 buildings. Accumulated experience has demonstrated that the prototypical buildings - educational or administrative - designed to be repeated often undergo alterations. The reasons for such changes are identified, along with their impact on the functionality, service life and future maintenance of such assets.*

Keywords: *Building's Life-cycle, Public procurement, Educational buildings, Asset management, Change.*

1 Introduction

Every building has a life cycle, a process that encompasses from its planning to the demolition / deconstruction stage and management of its waste. Although there are different interpretations and particularities that involve the type of building and the location where it will be constructed, the cycle begins with the planning phase, in which objectives and requirements are defined, as well as technical, economic, and environmental feasibility studies and projects are developed. It continues through the construction phase, and proceeds to the operation phase, which corresponds to daily use, maintenance and management in which replacements, repairs, and renovations in the building often occur. The last stage of the cycle corresponds to the end of its useful life. At this point, the building is disassembled or demolished. Its materials, parts, elements and components can be recycled or reused in some way, or the building itself may reused and taken to the initial stage of another/new cycle (Watson, 2003).

During each stage, in order to increase its useful life, there may be a need for changes/modifications to its physical structure. These changes range from small interventions, such as reorganization of interior finishes, to major alterations, such as additions of areas that may affect more than one system of the building. Changes may be related to "the need to reconfigure space to improve the flow of people, the desire for new services and equipment, as well as the accommodation of new users and types of use" (Keyme, 2000), etc. The period in which each change occurs during the building's life cycle may result in impacts on important factors related to the building's performance, such as its function, useful life, and maintenance.

According to the expected responses and interaction of each change with the systems and subsystems of a building, Slaughter (2001) classifies changes into three general types (Table 1): a) changes that may be related to alterations in its function, with the "objective of achieving a certain goal"; b) in its capacity, referring to "certain performance requirements, in loads/conditions or volume"; and c) flow, "to movements within and around a building in relation to the surrounding environment and its population of use".

Table 1. Types of changes in a building

Type of Change	Category	Response to
Function	Upgrade existing functions	Higher performance levels that require different components/processes
	Incorporate new functions	New facility performance objectives that require new components/systems
	Modify for different functions	Different objectives from change in usage class that require diferente components/systems/processes
Capacity	Change loads/ conditions	Higher expected performance under specic load conditions
	Change volume	Increased requirements for operable space per usage class
Flow	Change in environmental flows	Higher/different performance requirements for internal or surrounding environmental conditions
	Change in flow of people/ things	Different performance requirements for passage, movement or organization of people/things within/into facility

Source: Slaughter (2001)

The occurrence of changes in buildings over time is a concern for large corporations, government agencies and homeowners, as well as the occupants and users of these facilities (Slaughter, 2001). Depending on the type of building, it is not efficient, both economically and environmentally, to design and construct facilities with a short functional life. In fact and generally speaking, once the service life is reduced, the benefits that could be obtained are also reduced; costs and waste are generated for changes and/or demolitions, which reduces the return on the initial investment.

In the context of public procurement, understanding/mapping changes and their impacts becomes relevant, given the specific nature of the design process and the dynamics of constructions and bidding contracts, constrained by limited resources and planning/timeThis work presents an analysis based on the identification of changes/alterations that occur over time (period/type), their relationship with the systems and subsystems of the construction, and the impact generated by the changes (cost estimate, waste generation, and time-effort) at very early stages of the life-cycle process, adopting a public educational institution in Brazil as a case study.

2 Case Studies

2.1 Context of Public Procurement in Brazil

Public works are "planned and designed to be executed and completed within the stipulated deadline, estimated value, and in accordance with the legislation and parameters specified in the bidding notice" (Silva; Freitas, 2016). Unlike private sector companies that have autonomy to acquire, sell, lease assets, and contract services, public works carried out in most countries have to follow strict bidding and contracting procedures. In Brazil these processes must comply to the administrative procedure of bidding, linked to Law No. 14.133/2021 (reformulation of Law No. 8.666/93).

In addition to these basic premises, a public building must prioritize sustainability, that is, minimize the impacts generated on the environment and users, as well as be designed and built with a prolonged life cycle at viable construction and maintenance costs (Motta, 2005). However, despite regulation and transparency, studies have been developed in recent years (Esteves, 2012; Salgado, Brasil; Lomardo, 2013) pointing out that specific aspects and dynamics of the design processes, especially in public educational buildings, have impacted the performance of buildings over time.

Silva e Freitas (2016) also highlight that the variability of demands that are passed on as information and constraints to the design team, as well as the long time elapsed between the project conception and the execution of the work, can result in changes throughout the process, generating rework and delays in the schedule both in the design and in the execution. In addition, the constant and growing need for physical spaces leeds to the repetition of predetermined types of buildings, mostly in closed construction systems with little flexibility, in which the same buildings are reproduced in various locations as part of the education supply policy (Páscoa, 2008).

2.2 The Instituto Federal Sul-rio-grandense

The Instituto Federal de Educação Ciência e Tecnologia Sul-rio-grandense (IFSul) is part of the Federal Technical and Technological Education Network, created by Law No. 11.892 in December 2008. Currently, it has more than 120 buildings, totaling approximately 126.535.49m² of built area, distributed across 14 campuses and the Rectorate, in the state of Rio Grande do Sul/Brazil, implemented in different expansion phases. The buildings are intended for management, administration, teaching, research, and extension activities and were mostly built in separated, independent constructions, originally developed for this purpose or adapted. These spaces are managed and planned based on specific instruments and legislation that accompany the federal public administration, as mentioned earlier.

Over time, the building stock of IFSul has been expanded and modified as a result of the dynamic processes present in the educational institution. However, both decision-making and execution, as well as adjustments/changes, usually take place in a context of scarce resources (raw materials, energy, or - more commonly - money), which significantly affect the management and maintenance of these physical structures.

3 Materials and Methods

3.1. Description and Data Collection

For this study, buildings constructed in two units of IFSul, Venâncio Aires (VA) and Bagé (BG), were selected, which were built after the creation process of the Federal Institutes Network (2008) and began their activities in the new buildings in 2011. The projects were developed by technical professionals from the same institute, and the constructions were executed between 2009 and 2011. The buildings were built on a single ground floor with reinforced concrete structure, hollow brick masonry walls, anodized aluminum frames, ceramic finishes, and painting. They have orthogonal facades and are implanted in the precints according to the local legislations, climatic and geographical characteristics of their respective municipalities (Figure 1 and 2).

Figure 1. Campus Venâncio Aires.
Source: IFSul (2022)

Figure 2. Campus Bagé.
Source: IFSul (2022)

Two buildings were selected in each unit, one for administrative use (ADM) and the other for pedagogical use (PED), both presenting the same built prototype for their respective uses. The selection and definition of the case studies/buildings occurred due to access to data, as well as to the fact that these units had been built during the same period of institution expansion and presenting the same spatial layout and construction characteristics. Also, access to information regarding the changes made in the units over time was important for the the sample selection and the proposed analyses.

The data collection was carried out between September 2022 and February 2023. The documents (technical drawings, specifications, and budgets) related to the bidding project (basic project) and the executed project (as-built) were provided by the technical office of IFSul. The updated projects (current status) were prepared by the authors after visiting the sites for photographic survey and collection of complementary information.

3.3 Data Analysis

An analysis of the case studies was carried out based on:

a) Identification of changes and period: checks and comparisons were made between the plans in two periods A: bid (BID) and executed (EXC) projects and B: executed and updated (UPD) projects, for each selected building. The changes were mapped using graphic drawings and tables, organized by type of alteration, period and reason for its implementation. Afterwards, the changes were classified into three categories, based on Slaughter (2001): I. Function; II. Capacity; and III. Flow;
b) Relationship between the building's systems and subsystems and types of changes: matrices were created for each type of building analyzed (ADM and PED), based on the model proposed by Keyme (2000); and
c) Impact of changes: these were scored according to estimated cost, waste generation and time-effort required for implementation. The comparative selection method for adaptability measures (CSA), developed by Gijsbers and Lichtenberg (2012), was used to classify the changes.

4 Results and Discussions

4.1. Analysis of the Type of Change and Period Carried Out

From the data in Table 2, it is possible to observe that changes occurred in the buildings of the administrative blocks, both in the Venâncio Aires unit (VA) and in the Bagé unit (BG), in period A - bidding (BID) and execution (EXC) and in period B - execution (EXC) and update (UPD).

Table 2. Identification of the categories of changes made to the administrative blocks, in periods A: between bidding (BID) and execution (EXC) and B: between execution (EXC) and update (UPD), at the Venâncio Aires (VA) and Bagé (BG) Campuses.

Administrative Block									
Campus		VA				BG			
Changes									
Periods		A: BID - EXC	B: EXC-UPD	T	%	A: BID-EXC	B: EXC-UPD	T	%
Category Type	I	6	5	11	36,6	3	4	7	53,8
	II	2	1	3	10	0	2	2	15,4
	III	5	11	16	53,4	1	3	4	30,8
Total		13	17	30		4	9	13	
Variation		+4				+5			

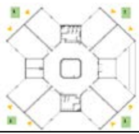
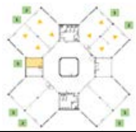
Caption: I. Function; II. Capacity; III. Flow. Source: Prepared by the authors (2023)

The greatest number of changes, in both Campuses, occurred just after the construction period of the building. In VA, 17 changes were made, and in BG, 9 changes were made. The BG Campus had a total number of changes (13) lower than that of VA Campus (30). These values can be explained by the difference in the bidding phase periods. BG was bid after VA, and it can be observed that some changes identified in the period A of ADM VA were not observed in the same period for BG.

When analyzing the categories of changes between the periods, VA presented a reduction in categories I and II but had an increase in category III, which accounted for 53.4% of the total changes observed in the block. These changes are related to the execution and removal of lightweight partitions, closures of windows/openings, which reconfigured the flow/circulation of environments inside the building. For BG, category I presented the highest values (54.8%), compared to the total number of changes in the block. These were changes related to the function of spaces, installation of equipment for improvements, and small modifications in the interior spaces of the building.

The Pedagogical Blocks (PED) also underwent changes, both in period A and B, but in the VA Campus block, there was a reduction in the number of changes between periods (Table 3). Comparing the number of changes between Campuses, a total of 04 changes were identified in the PED BG block, and 15 changes were identified in the PED VA block. As with the administrative block, there was also a reduction in the total number of changes between Campuses in the periods. However, when looking at the most significant category, "function" (I) represented the highest values, 40% in PED VA and 75% in PED BG.

Table 3. Identification of the categories of changes made to the administrative blocks, in periods A: between bidding (BID) and execution (EXC) and B: between execution (EXC) and update (UPD), at the Venâncio Aires (VA) and Bagé (BG) Campuses.

Pedagogical Block									
Campus		VA				BG			
Changes									
Periods		A: BID - EXC	B: EXC-UPD	T	%	A: BID - EXC	B: EXC-UPD	T	%
Category Type	I	2	4	6	40	0	3	3	75
	II	4	1	5	33,3	0	0	0	0
	III	2	2	4	26,7	1	0	1	25
Total		8	7	15		1	3	4	
Variation		-1				+2			

Caption: I. Function; II. Capacity; III. Flow. Source: Prepared by the authors (2023)

4.2. Relationship between Construction Subsystems and Types of Change

Table 4 presents the interaction matrix between subsystems and categories of the type of change analyzed in the administrative blocks. The most significant evidence of interaction in the ADM blocks was observed in the "finishing" system, both in VA and BG. It is also observed that the "structure" system did not interact with the categories in the changes identified in BG. This can be explained by the fact that the observed changes are not related to changes in volume and/or new elements that impacted the infrastructure and superstructure of the building.

The PED block presented the greatest interactions in the "services" system (Table 5), with a focus on the "electrical and logic installations" subsystem in both Campi. It is observed that in VA, the changes impacted the "environment" system and the "wall" subsystem. In both VA and BG, adjustments were made to the dimensions and positioning of the windows/openings in the buildings, to improve both function and capacity and the flow of the environments.

Table 4. Relationship between systems/subsystems and changes in administrative blocks

Administrative Block																													
		Building Systems and Subsystems																											
		Structure				Environment						Services												Finishing					
Campus		VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG
Type of Change		Sub		Super		Wall		Roof		Abertur		Ventil.		Ar Cond.		Ilumin.		Eletrica		Logic		Plumbi		Flor		Wall		Abertur		Ceiling	
I	Upgrade																												
	New Function																												
	Modification																												
II	Conditions																												
	Volume																												
III	Envirometal																												
	People/Things																												

Caption: I. Function; II. Capacity; III. Flow. Source: Prepared by the authors, 2023, based on the model proposed by Keyme (2000)

Table 5. Relationship between systems/subsystems and changes in pedagogical blocks.

Pedagogical Block																													
		Building Systems and Subsystems																											
		Structure				Environment						Services												Finishing					
Campus		VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG	VA	BG
Type of Change		Sub		Super		Wall		Roof		Abertur		Ventil.		Ar Cond.		Ilumin.		Eletrical		Logic		Plumbin		Flor		Wall		Abertur		Ceiling	
I	Upgrade																												
	New Function																												
	Modification																												
II	Conditions																												
	Volume																												
III	Envirometal																												
	People/Things																												

Caption: I. Function; II. Capacity; III. Flow. Source: Prepared by the authors, 2023, based on the model proposed by Keyme (2000)

4.3 Impact of Changes

Regarding the impact of changes on cost estimates, waste generation, and time/effort required for implementation, Table 6 presents the scores per category, stage, and analyzed block.

Table 6. Impact score of changes in blocks, in periods A: between bidding (BID) and execution (EXC) and B: between execution (EXC) and update (UPD), in Campi Venâncio Aires (VA) and Bagé (BG).

	Administrative Block (ADM)								Pedagogical Block (PED)							
Campus	VA				BG				VA				BG			
	Pont.				Pont.				Pont.				Pont.			
Periods	A	B	T	%	A	B	T	%	A	B	T	%	A	B	T	%
I	10	8	18	20,2	7	9	16	48,5	13	16	29	36,7	0	9	9	60
II	14	2	16	17,9	0	6	6	18,2	28	4	32	40,5	0	0	0	0
III	27	28	55	61,8	3	8	11	33,3	12	6	18	22,8	6	0	6	40
Total	51	38	89		10	23	33		53	26	79		6	9	15	

Legenda: I. Função; II. Capacidade; III. Fluxo. Fonte: Elaborado pelos autores, 2023

The scores for the VA Campus blocks showed an increase between period A and B, while the BG Campus showed a reduction in both the administrative and pedagogical blocks. The changes made in the administrative blocks had the greatest impacts, with higher values in period A, 51 points for VA and 53 points for BG. In the ADM block, the greatest impacts for the VA Campus were in the "flow" change category (61.8%), whereas in the BG Campus, the "function" category (48.5%) had the highest percentage. Regarding the PED block, for the BG Campus, the "function" category (60%) again had the greatest impact, and for the VA Campus, it was the "capacity" category (40.5%).

5 Conclusion

Buildings are often designed and maintained to have a long service life. As a function of their use and various impacts/interferences, some changes may be required throughout their useful life. Although common assumptions point out that, generally, changes are concentrated on interior services and finishing systems, the research shows that changes made over time, in public buildings for educational use, impact on all building systems and occur in both periods studied.

This research presents the alterations and their relationship with building subsystems and the impact that changes can have on the life cycle of buildings, considering the categories of function, capacity and flow over time. Based on the data and analysis of the case studies, the research demonstrates that changes occur from the early stages of the building life cycle, impact on expected costs and overall building efficiency over time.

The largest number of changes occur between the conclusion of the execution and the current phase of the building (EXC - UPD), which corresponds to a very early stage of the period of operation and maintenance of the life cycle of the building. In the first stage, changes tend to fine tune functional of programmatic needs of the users/specific activities; later on, the changes are more directed to the "flow" and the "function", such as the reorganisation of the areas and spaces to accommodate a new use class in a small scale, to adjust/integrate existing functions and to comply with specific legislation. The greatest impacts in relation to cost estimates, waste generation and time-effort, occur in the alterations related to the expansion and reduction of areas not initially foreseen in the project, as well as in the change of installations/services incorporated (embedded) in the building. They interfere in structural systems and interior/exterior closing systems and have an impact on efficiency and cost estimation.

References

Brasil (1993), "Lei nº 8.666, de 21 de junho de 1993". Lei Licitações e Contratos. Brasília, DF, Senado Federal.

Esteves, J. C. (2012), "Planejamento e Gestão do Ambiente Construído em Universidades Públicas". Dissertação. *Dissertação de Mestrado* – Programa de Pós-Graduação em Engenharia Urbana, UFSCar, SP.

Gijsbers, R., Lichtenberg, J. J. N. (2012). "Comparison of adaptability measures in building design – CSA Method: Functionally effective and technically efficient design founded on (future) user demands". In Proceedings of the12th International Conference on Design & Decision Support Systems in Architecture and Urban Planning (DDSS 2012), august 27th-29th, (blz. 1-16). Eindhoven University of Technology.

Keymer, M.A. (2000) "Design strategies for new and renovation construction that increase the capacity of buildings to accommodate change", *Master of Science*, MIT, Cambridge, MA.

Motta, C. A. P (2005), "Qualidade das obras públicas em função da interpretação e prática dos fundamentos da Lei nº 8.666/93 e da legislação correlata". In: Simpósio Nacional de Auditoria de Obras Públicas, 10, Recife.

Páscoa, O. N. F. A (2008), "Qualidade do lugar em escola pública padronizada do Rio de Janeiro Estudo de caso Escola Municipal Tia Ciata". *Dissertação de Mestrado* - Universidade Federal do Rio de Janeiro. Rio de Janeiro.

Salgado, M. S.; Brasil, P. C.; Lomardo, L. L. B (2013), "Entraves na gestão do processo de projeto de edificações públicas: uma análise da Lei nº 8.666/93". Anais... Campinas: ANTAC.

Silva, R. C. da; Freitas, L. de S. (2016), "Diretrizes para a fase de projetos de edificações públicas sob o foco da sustentabilidade ambiental: estudo de caso de uma Instituição Federal de Ensino Superior (IFES) de acordo com o sistema de certificação LEED". Interações, Campo Grande, MS, 17(4), 767-780.

Slaughter, E.S. (2001), "Design strategies to increase building flexibility", Building Research & Information, 29(3), 208-217.

Watson, S. (2003), "The building life cycle: a conceptual aide for environmental design", 37th ANZASCA Conference Proceedings, Sydney 2003, Editor S. Hayman, pp 642-652.