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Portugal's Rising Research in Architecture and Urbanism: The influence of international research centres and authors.

Abstract

In the early 1960s, Portugal saw a rise scientific research on architecture and urbanism at the National Laboratory of Civil Engineering (LNEC), fundamental to support the Government in establishing a national program for housing, which continued until the fall of the Dictatorship in 1974. Lacking tradition in scientific studies in architecture and urbanism, a group of young architects with knowledge of references from international researchers and research centres, gathered encouragement and opportunities to develop their own research works and methodologies, and later, to question the application of such scientific methods. This paper aims to identify and discuss the strategies and methodologies explored to develop these seminal researches, retrieving and reappraising LNEC's archived documents and oral testimonials from former researchers. We aim at exposing the foundations of Portuguese scientific research on architecture and urbanism and its contributions to an international audience.

Keywords

The Portuguese National Laboratory for Civil Engineering, scientific research, history of architecture and urbanism, history of scientific research, Nuno Portas.

The Portuguese National Laboratory for Civil Engineering – *Laboratório Nacional de Engenharia Civil* (LNEC) – was created in 1946 by the Ministry of Public Works and Communications, to strengthen its response to the upsurge of public works in Portugal

and its colonies.¹ At this time LNEC's research work was limited to three services, managed by renowned Portuguese engineers and developed by only a few researchers.² Nevertheless, in 1952, with the opening of the new campus (Figure 1), the number of LNEC employees increased tenfold. To manage growing requests for studies and trials in the early 1960s, departments and respective divisions were redefined, with engineer Manuel Coelho Mendes da Rocha (1913-1981) as LNEC's Director (1954-1974).

(please insert here figure 1)

Figure 1. The Portuguese National Laboratory for Civil Engineering (LNEC)

Source: Salvador de Almeida Fernandes, c. 1952, Arquivo Municipal de Lisboa, PT/AMLSB/CMLSBAH/PCSP/004/SAL/000148.

While according to the first organic law, LNEC's key aim was to “undertake, promote and coordinate the investigations and experimental studies necessary for the achievements and progress of civil engineering”,³ new research areas were expanded and integrated into new fields of knowledge, including architecture and urbanism. Subsequently, the Construction and Housing Division (CHD) was created and integrated in the Buildings and Bridges Department (1961).⁴ Moreover, at this particular moment, some universities were promoting several similar research studies. Thus, Portugal witnessed a growing concern for the definition of a national scientific policy.⁵

Developed by a small number of young architects, with little experience in research, the first works conducted at this new division (CHD) were mostly intended to inform the relocation of people living in poor building conditions. The goal was to tackle a national deficit of five hundred thousand houses, partly caused by a spike in demography and internal migration.⁷ Thus, to support necessary transformations in cities, the CHD started

to centre its studies on construction materials, on construction processes and on housing. CHD's main manager, engineer Ruy Gomes (died 1985), had invited architect Nuno Portas (born 1934) to cooperate and manage the areas of architecture and urbanism. At the time, Portas was a member of the editorial board *Arquitectura* (1958-1970),⁸ then the main Portuguese architecture journal, and was also a partner (1957-1975) of Nuno Teotónio Pereira (1922-2016), an architect strongly engaged with the *Federação de Caixas de Previdência* (the Portuguese Federation of Pension Funds, Economic Housing of the Ministry of Corporations).¹⁰ Portas saw in LNEC the possibility of “constituting a research team with people from the humanities and engineering, prioritizing works on the perceptions and use of spaces”.¹¹ In order to start the first research works, Portas invited architects Bartolomeu da Costa Cabral (born 1929), Francisco Silva Dias (born 1930), Maria da Luz Valente Pereira (born 1934), Gonçalo Byrne (born 1941) and António Reis Cabrita (born 1952), as well as the trainee architect Alexandre Alves Costa (born 1939) and the architecture students Manuela Fazenda (born 1947) and Helena Roseta (born 1947), who had worked with him at Teotónio Pereira's office and/or whom had a temporary experience in scientific research outside Portugal.¹² These architects blatantly opposed the Portuguese dictatorship,¹³ and were visibly uncomfortable with the obscurity inherent to national academic architecture. Thus, they saw in LNEC, a public institution, their opportunity to explore how architecture could respond to urban and social problems of the time, particularly lack of housing and its resulting social problems, which were well in the sight to all, especially those living in the capital.

Currently, all these researchers are retired from LNEC. Yet, their memories and testimonies constitute a valuable source of information, accounting for their life experiences and the research studies they carried at LNEC. The lines of research, methodologies, and influences they inherited or found abroad, can still be collected from

their oral testimonials and through a detailed analysis of the research materials still archived at LNEC, but which have been so far more or less overlooked by the scientific community. The same does not apply to researches undertaken at some international research laboratories, which have already been the object of studies by the scientific community.¹⁴ Indeed, in recent years, references to the research conducted at CHD occurred sparsely, and most related specifically to the work of architect Nuno Portas.¹⁵ Thus, the works conducted by Valente Pereira, Alves Costa, Costa Cabral or Silva Dias, all of whom collaborated with Portas at LNEC's CHD, have somehow been forgotten over time. There are also several authors that do include information about LNEC's works at the international scientific and technological arena, but mainly relating to engineering research areas.

Given the inexperience of Portugal with housing and urban research, at the CHD, Portas felt the need to consider from initial studies, the influence from research lines and methodologies carried out in homologous centres or from authors he considered to be main references, thus showing availability to learn from others. Nevertheless, as will be seen in this article, by the time CHD's research works were developed and disseminated, some of it was conversely deemed of interest to international institutions and researchers. It is in this context that the present research has identified architecture and urbanism methodologies applied at LNEC as a particular case-study.

Undoubtedly, as reported by former CHD researchers, who were interviewed in the scope of this research, the knowledge acquired by LNEC's work was exposed in Universities, where some of LNEC's researchers were professors,¹⁶ but also put to practice in real life, in the development of housing or urban projects. As testified by Silva Dias:

I usually say I am a lucky architect. There must be very few architects in the world to whom the State paid for a research study on evolutionary housing. And afterwards, History brought on a revolution which made it possible for these architects – me and Nuno Portas – to apply the theory and the research results in the Zambujal project [(1969-1976)]. To me as an architect and to Portas as State Secretary for Housing, it was extraordinary luck to do the study and then apply it immediately.¹⁷

By making use of the valuable oral testimonials of these researchers and of a detailed analysis of LNEC's archived reports (1961-1974), this article aims to inform the reader about: 1) the reasons motivating LNEC to develop such research themes in the domains of architecture and urbanism; 2) the works developed at LNEC related to the study of housing and territory; 3) the research methodologies which were followed and applied, and 4) the international studies and authors considered as references. Furthermore, the contextualization of this information within research methodologies adopted on architecture and urbanism, aims to put into perspective what other scientific domains aided the development of those from CHD.

In order to expose what methodologies and influences from abroad concurred to the development of scientific studies in architecture and urbanism in CHD, this paper is structured in eight parts. After this introduction, the second part offers a brief overview of research in architecture and urbanism outside Portugal. The most relevant investigations focused on housing and urban research developed at LNEC are presented in the third part. The following four sections correspond to the description of CHD's main researches focused on housing and urban space and its respective applied methodologies.

Finally, a discussion and the main conclusions drawn from the present research are exposed in the last part of this article.

The architecture and urbanism research overseas

To better understand the Portuguese context of scientific research in architecture and urbanism, and to identify influences it received from abroad, it is fundamental to consider some experiences from foreign researchers. One of the first attempts of the twentieth century to promote scientific investigation in architecture dates back to the vanguard of the Modern Movement, during the 1920s and 1930s, when the study about Minimum Housing was developed as a “scientific investigation of the sociological fundamentals of architecture”, as testified by Karel Teige (1900-1951).¹⁸ Perhaps the most evident case of this disciplinary evolution is in the works by Alexander Klein (1879-1961), whose practical results can be observed in his graphical method of qualitative evaluation of housing, known in Portugal since the 1930s.¹⁹ Another example, focused in urban form, is the investigation developed by Walter Gropius (1883-1969) on how the number of floors impacted insolation and distance between buildings, which was defended in several international meetings, including the International Congress of Modern Architecture (CIAM) of 1930.²⁰ It is also worth recalling a handbook, still considered a seminal reference around the world, the *Architects' Data* (1936) by Ernst Neufert (1900-1986), who was Gropius's collaborator.²¹ This handbook resulted from an exhaustive investigation about the sizing and performance of functions in architectural spaces.

In the aftermath of World War II some academic and State research centres interested in architecture and urbanism would be established in Western Europe but also in the USA. One of these was located at the University of Cambridge, founded after the arrival of Leslie Martin (1908-2000) to the Department of Architecture, in 1956. Sustaining a

continuous relationship between research, teaching and professional practice, culminating in the inauguration of the Centre for Land Use and Built Forms Studies (LUBFS, 1967), its main goal was to apply geometrical principles to the occupation of territory and built forms, but also to improve housing programs, and further develop previous research lines such as those relating computational application to architecture or history of art and architecture. Mário Krüger (born 1945), a Portuguese architect who completed his PhD at the University of Cambridge (1978), immediately pursued his work at LNEC, where he stayed between 1978 and 1980. In his work he emphasized the relations of density of inhabitants with height and shape of buildings in urban space, which Portas, as we shall see further on, considered fundamental for CHD investigations:²²

When Krüger decided to return [to Portugal], I was happy because I thought he could continue [at LNEC] the Leslie Martin line of research.²³

It was precisely in this period that Christopher Alexander (born 1936), graduated in architecture and mathematics, obtained his PhD at the University of Harvard. While focusing on design methods, he would later publish the well-known book *Notes on the Synthesis of Form* (1964).²⁴ After his collaboration with Serge Chermayeff (1900-1996), Alexander also published the book *Community and Privacy* (1963), addressing housing issues through the use of diagrams. It was the beginning of his career as a researcher and experimenter in architectural design worldwide.²⁵ In Portugal, Alexander's influential article, "The city is not a tree" (1965), would be translated into Portuguese and published by Portas for the *Arquitectura* journal, a main reference for Portuguese architects.²⁶

In France, a country with centralized organization, public policy for research in architecture was curiously initiated by the Minister of Culture in 1972. This policy has its roots on the *Direction de l'Architecture du Ministère de l'Urbanisme, du Logement et des Transports* (Department of Architecture of the Ministry of Urbanism, Housing and Transport), who conceptualized a strategic vision and a specific knowledge in 1963, remaining active until 2003. Such a policy arose particularly after architecture courses departed from Schools of Fine Arts, after May 1968, and became independent schools under the Ministry of Culture.²⁷ This step allowed for a greater dialogue between architecture studies and the human sciences, but also the history of the city and its form, enabling a greater reflection about the advantages of a disciplinary autonomy. With respect to the latter, Philippe Boudon (born 1941) stood out with his researches on architecture epistemology (1975),²⁸ while the study of city form was explored by several researchers, including the study *Formes urbaines: de l'îlot à la barre* (1977) by Philippe Panerai (born 1940), which can be considered here as seminal one.²⁹ In 1983, the scientific journal *Les cahiers de la recherche architecturale* listed financed research projects developed from 1973. Thirteen research projects were mentioned for 1973/74, covering areas such as design and building, technical matters, heritage, architectural profession, city, teaching, and theory, showing the large scope of the disciplinary field.³⁰ In this same issue, publisher Francis Chassel, refers to the first official talks about the arrival of architects to the main French research system *Centre National de la Recherche Scientifique* (CNRS, the French National Centre for Scientific Research) in the year of 1977.³¹

In 1984, the colloquium *Rencontres, Recherche, Architecture* (*Meetings, Research, Architecture*) sought to promote a world overview of research in architecture.³² However, in the end, the colloquium revealed that in the USA, research in architecture

was limited and mostly developed within the universities. That was the case of the work conducted by Kevin Lynch (1918-1984) and Edward T. Hall (1914-2009), both widely known by architects through their published books.³³ In the case of Italy, research on the study of the urban realm gained greater attention in the 1960s, particular at the academia, through the studies and publications of several architects, such as Aldo Rossi (1931-1997), Carlo Aymonino (1926-2010), Gianfranco Caniggia (1933-1987), Giorgio Grassi (born 1935) and Saverio Muratori (1910-1973), who pioneered a number of typomorphological studies and directed their theories towards buildings and urban developments, including the INA-Casa building programme (1949-1963). Finally, it should be noted that in Sweden, in 1945, a research policy was implemented for architecture, essentially to support state-owned housing construction of the Post-World War II period. Yet, a number of other architect researchers, such as Norberg-Schulz (1926-2000), who studied in Norway, Switzerland, Italy and in the USA, also devoted themselves to fundamental research (theory), and consequently published their work, as is the case of the first book on disciplinary structuring, *Intentions in Architecture*,³⁴ a brief portrait of a broad-spectrum career in architecture, led by deep research with solid cultural foundations.

Research in Architecture and Urbanism developed at LNEC

All the above-mentioned research centres were known to LNEC researchers, namely through study missions, and through a number of publications. Indeed, as exposed in its Organic Law, “the exchange of scientific, technical and related resources, national and foreign, in particular through study visits, participations in congresses and other meetings and the exchange of publications”³⁵ was expected from LNEC (Figure 2). Thus, numerous scientific works published by international researchers and research centres were

purchased regularly by LNEC, specifically on ongoing research thematic lines. LNEC promptly made these publications available to all researchers in LNEC's library, later these would circulate internally (Figures 3 and 4).

With respect to the specific area of architecture, Portas, as a journal editor, was particularly well informed about what was being published overseas, and through LNEC ordered several reference books and scientific journals for his research group which, in the dictatorship period, would hardly have arrived to Portugal otherwise. As witnessed by Valente Pereira:

LNEC ordered many different books (...) if there was someone that Portas would like to invite for being an expert in a specific matter, LNEC would also invite them to share their knowledge and discuss with us. (...) Portas' international relations came to LNEC! Any book we wanted. I read a book, the bibliographic notes and then, if there were any other books that seemed interesting, LNEC would buy them.³⁶

Among many other authors, LNEC's former researchers had access to books written by Paul-Henry Chombart de Lauwe (1913-1998), Odd Brochmann (1909-1992), Lennart Holm (1926-2009), Serge Chermayeff, Christopher Alexander, Leslie Martin and Kevin Lynch. Such books of international reference, circulated also outside this laboratory, widening the small research community and architecture students from Lisbon School of Fine Arts, through the teachers Portas and Silva Dias, but also reaching some private architecture offices through book exchange.

(please insert here figure 2)

Figure 2. Valente Pereira at the conference *Segundas Jornadas de Engenharia e Arquitectura do Ultramar* [Second Overseas Engineering and Architecture Days], Luanda May 20, 1969 and at the course “O uso do espaço na habitação” [“The use of spacing in housing”], LNEC, February, 1974.

Source: Maria da Luz Valente Pereira personal archive.

(please insert here figure 3)

Figure 3. Open access library of LNEC’s common room

Source: Nuno Barros Roque da Silveira, 1970, Arquivo Municipal de Lisboa, PT/AMLSB/CMLSBAH/PCSP/004/NBS/000236.

(please insert here figure 4)

Figure 4. LNEC’s common room

Source: Nuno Barros Roque da Silveira, 1970, Arquivo Municipal de Lisboa, PT/AMLSB/CMLSBAH/PCSP/004/NBS/000233.

A growing awareness of the importance of LNEC’s research on housing, made collaboration with Portuguese official bodies imperative, and this included the *Fundo de Fomento da Habitação* (the Housing Development Fund), city councils (particularly of Lisbon) and the *Federação de Caixas de Previdência* (Federation of Pension Funds),³⁷ the latter through Teotónio Pereira’s strategic role and proximity to Portas.³⁸ Contacts with foreign research centres were also considered by LNEC, as already argued. One of the first times that Portas used his connections with foreign researchers to define the thematic lines and main methodologies to apply at in his division at LNEC, was in 1965

at the 8th Congress of the International Union of Architects in Paris. As reported by himself in his field work report, handed to LNEC after his international mission, several contacts were established and compiled, mainly with organizations and personalities of great interest to the studies related to those that were being developed at CHD.⁴⁰

Through an analysis of LNEC's archives, it was possible to identify more than one hundred publications edited by LNEC between 1961 and 1974. These publications, namely reports, technical information and memoirs, allow the identification of a variety of themes, such as: 1) functional and construction types of housing; 2) family housing needs; 3) sizing of dwellings and its divisions; 4) programming and rationalization of housing projects; 5) social housing; 6) technical advice; 7) approval of construction materials; and 8) construction processes. In the scope of this article our focus is on the most relevant investigations regarding housing and urban research (Table 1). To develop such studies, the CHD group relied mostly on literature review, but also in the application of different methodologies, some previously explored by international research centres. Among other methodologies, from LNEC's reports, it was possible to identify the following ones: 1) surveys and questionnaires; 2) mathematics and computer analysis; 3) databases; and 4) design. It should be stressed that some works made use of more than one methodology. Thus, it is not possible to identify one specific pattern of methodologies applied at LNEC. As these works were being developed as preliminary investigations, and their exploratory approach required the testing of different possibilities including methods to examine the various problematics under analysis at that time in other centres.

(please insert here table 1)

Table 1. Most relevant researches in architecture and urbanism elaborated at LNEC (1961-1974)

Source: Authors

Surveys and Questionnaires

The first studies conducted at CHD were carried out essentially towards a public awareness of the notion of “well-being”, a concept directly related to architecture and urbanism.⁴² Thus, as soon as Portas joined the LNEC team, one of the proposals he presented to his superiors was for a research work where he could ask people exactly how they use their homes.⁴³ But how was that possible within a political regime that precluded freedom of expression? The book *Refute... social problems*, discussing housing policy, had been censored;⁴⁴ The edition of the third volume of the *Rural Housing Survey* had also been censored;⁴⁵ the *Survey of Portuguese Regional Architecture*, as proposed in 1949 by Keil do Amaral, was delayed until 1955-1960 because of financial and political difficulties;⁴⁶ thus how could Portas propose to study the way people, mostly new urbanites arriving from rural areas, occupied their homes? His justification emphasized the need to rationalize design and construction, to offer better future architectural projects for municipal social buildings.

From all the available LNEC reports and documents analysed in the scope of this article, there is no sign that any was censored. Yet, before their publication, all research works were subjected to a full analysis by the authority of the head division.⁴⁷ This situation contributed to a practice of self-censorship by LNEC researchers, as witnessed by Valente Pereira.⁴⁸ Fazenda also confessed that, at a certain time, LNEC had a doorman charged with informing the Portuguese political police (PIDE) about any suspicious

activities. For instance, the theatre group directed by the stage director João Silva (death 2018), which held some auditions at the LNEC auditorium, was under observation by PIDE, which reveals the political pressure characteristic of that time.⁴⁹

Thus, as expected, one of the first works developed at CHD was the study titled *Pilot survey on housing family needs* (1963).⁵⁰ For the development of this research it is worth noting that, at the UIA Congress, Portas met with the engineer Gérard Blachère (1914-2011), in charge of the *Groupe d'étude des besoins de l'homme dans l'habitation* (the Study group on human needs in housing) from *Centre Scientifique et Technique du Bâtiment* (CSTB), a French scientific and technical centre for building, of interest to the Portuguese Laboratory for its shared lines of study.⁵¹ As suggested by Portas, their “study of experimentation in real dwellings” presented many similarities with the aims of the pilot survey conducted then at LNEC,⁵³ which sought to “ascertain the modalities of dwelling usage, according to two orders of variables: different families and different conceptions of dwellings organization and its grouping”.⁵⁴

Although the CHD team charged with developing the pilot survey included architecture and engineering students, the task and its methodology were mainly sociological, and as such this research had the support of the Portuguese sociologist Adérito Sedas Nunes (1928-1991), a close friend of Portas,⁵⁶ who is considered a fundamental researcher for the data collection process.⁵⁷ Thus, the preparation of the standard questionnaire and the determination of the social groups were prepared according to other international surveys.⁵⁸ In Portugal, the work consisted in a visit to each dwelling, conducted by the survey team, in order to register the placement of furniture and household equipment in the architectural plan, and to conduct a questionnaire addressed to the housewife. The knowledge acquired through the questionnaire in North Olivais residents, proved extremely useful to Portas in the later

development of architectural housing projects, such as cell C of South Olivais (1959-1968), by Portas and Costa Cabral in articulation with the technical housing office from the Lisbon municipality.

From Paris, Portas also followed the research methodologies applied at the *Centre d'Études des Groupes Sociaux* (Social Group Study Centre), particularly by Paul-Henry Chombart de Lauwe, Claude Cornuau (born in 1948) and Maurice Imbert (born in 1930). Moreover, the surveys conducted by Chombart de Lauwe were indicated as strategic for the methodologies followed in CHD's pilot survey. Chombart de Lauwe was acknowledged by Portas as an important reference since his student years, as visible in his final thesis submitted for the degree of architecture (1959).⁵⁹ Furthermore, at the colloquium titled *Social aspects in the construction of habitat* (1960), organized by the *Sindicato Nacional dos Arquitectos* (Portuguese National Association of Architects), of which Portas was a commissioner, Chombart de Lauwe delivered a lecture on the surveys he had carried out. Unknown to Portuguese architects, this French sociologist was afterwards invited by Portas to publish a Portuguese translation of his article "Housing Sociology. Methods and Perspectives of Research" in the *Arquitectura* journal.⁶⁰ By introducing this reference author to the LNEC research team, Portas also promoted a more scientific approach to architectural and urban issues, grounded on sociological methods.

Moreover, at the meeting of the W45 Commission of the *Conseil International du Bâtiment* (International Building Council), which took place at the UIA 1965 Congress, Portas concluded that studies established for CHD were appropriate, namely "following the double path: inquiry of human needs and preparation of methods and instruments to integrate the growing information available in a more objective process of project".⁶¹ So, while numerous studies on housing were being developed at LNEC, others, related to territory, would also begin to take place.⁶² Following the experience acquired from the

pilot survey, LNEC proceeded the research through other surveys which focused on urban space, namely the *Survey on urban housing*.⁶³ Its purpose was to understand what it was like to inhabit a specific dwelling-type and to examine and record domestic activities, evaluating the relation with outside areas, that is, “the urban life from which it is increasingly independent”.⁶⁴

Sharing such urban concerns, another important study conducted at CHD was titled *Organization and quality of urban space: pilot survey on the use of the city*,⁶⁵ which would be supported by the model proposed by Jay Wright Forrester (1918-2016) in *Urban Dynamics*.⁶⁶ Although Forrester proposed to simulate the life cycle of an urban area, at LNEC, the proposal was to create a model that would serve as “an instrument of analysis for the decisions of the direct interventions (for the project) in the urban system”.⁶⁷ At the urban scale, the dynamic model of the urban system information, was based on the pilot survey on the use of the city, which sought to determine the “relationship between some characteristics of the user and some characteristics of city use”.⁶⁸ The process of defining elements of the urban system was based on empirical observation, supported by a set of hypotheses. According to Valente Pereira, they “tried to describe the object (urban zone) and the external elements with which they are related, determined by the objectives (design information), highlighting and defining each of its characteristics”.⁷⁰ The work was completed with a postal questionnaire, a face-to-face interview, and city maps where the locations of the dwelling and the workplaces of the reporting population were marked. Consequently, the dimensions of the territories that “satisfied the greatest number of the system requirements” were collected.⁷¹ Although the urban housing surveys revealed some problems,⁷² the experience acquired with these researches was later pivotal for Valente Pereira’s collaboration (1979-1982) with the housing development fund, namely of Almada-Monte da Caparica Integrated Plan (1972-1983, Figure 5).⁷³

(please insert here figure 5)

Figure 5. Almada Integrated Plan: Monte da Caparica, 1^a phase (Raposo zone)

Source: DGPC/SIPA FFH DES.10459

Mathematics and computer analysis

Technological advances were fundamental in developing further research methodologies. As verified, besides sociology, LNEC researchers paid also attention to other methodologies of study, namely those regarding to mathematical decomposition and computer analysis, which Portas followed minutely. These were initially implemented at CHD by Alves Costa, to explore the *Rationalization of housing solutions*.⁷⁶ At the UIA congress, the working sessions with the Habitat Commission advocated the work from the Research Institute of Construction and Architecture (VUVA, Czechoslovakia) and at the Building Research Station (BRS, England). With respect to the session of UK delegate George Anthony Atkinson (born 1946), responsible for the architecture and urban planning studies at the BRS, Portas was particularly interested in his design process methodology, based on a systematic analysis of programs led by Christopher Alexander (1964), previously acknowledged by Portas.⁷⁸ From the meeting with the Czechoslovak delegate, Hanna Stašková, Portas highlighted his interest in a work published in the *Cahiers du Centre Scientifique et Technique du Bâtiment*, the CSTB scientific journal, focusing on rationalizing construction solutions and with similarities to Alves Costa's research. This work, which sought to program and rationalize social housing projects, tried "to reduce the non-significant variety and optimization of types and also the production of new functional schemes of the house".⁷⁹ Contributing to such work was the information collected in surveys which was analytically investigated to transform their original matrix into a numerical one, accessible to mathematical and

computer-based calculations.⁸⁰ Thus, sixteen functions/activities/services for the house, defined beforehand by Portas in the *Study of the functions and requirements of housing areas*,⁸¹ were transcribed in a questionnaire of about three hundred questions and organized according to a binary answer system (of 0 or 1).⁸² As Alves Costa noticed, to depict eventual design problems, “Portas was interested in the measurements of each housing function, but also in the relationship between functions”,⁸⁴ subsequently registered as a set of graphs. Portas and Alves Costa identified some changes occurring with the roles of the Portuguese women in their house, in particular because of their new job engagements outside the home. It should be notice that, until April 25, 1974, Portuguese women were mostly devoted to their husband and family, most of them being housewives. Women’s rights were so limited that they could only leave the country if their husband authorized it.

Still attempting to rationalize the act of designing, the study *Grouping of spaces from contiguity graphs*,⁸⁵ was developed by informatic engineers at LNEC’s Architecture Division to “obtain experience of computer representation and manipulation of the space elements”.⁸⁶ This research presented great similarities to the work by Philip Steadman (born 1942), which constituted an important instrument for decisions about buildings and urban areas.⁸⁷ Taking into account the work using Computer-Aided Design (CAD) driven by Christopher Alexander in 1964, LNEC presented, once again in the form of graphs, several schemes for grouping spaces, and restricting the composition “to the set of intentions of the designer that can be expressed at a given moment by an instruction of a contiguity”.⁸⁸

Finally, about the study *Implementation of an urban model for the Lisbon Metropolitan Area*,⁸⁹ it is important that, as mentioned by its author, this research consisted on the application of “LUBFS urban model”, considered by LNEC’s

researchers adequate to test and evaluate different strategies for the urban planning of Lisbon and its metropolitan area. LUBFS provided to LNEC a package of automatic calculation programs related to planning models; while Marcial Echenique and Tomás de la Barra, architects researching for LUBFS, provided the needed support. Regarding land use, occupancy policies, industrial location, establishment occupancy and density indexes, this study emphasized the “transportation system”.⁹⁰ This model, built on a set of equations based on quantitative analysis, was completed with cartography, maps, and censuses, allowing the visualization of three types of location sub-models: 1) covered area; 2) residential population; and 3) services. LNEC’s results were later exposed by Portas on the LUBF’s conference, *Urban Development Models* (1975).

Databases

With respect to analytical approaches, Portas developed the *Study of the functions and requirements of housing areas*.⁹⁹ This study, also supported by the results of the previous pilot survey and on the analysis of different national and European regulations, addressed the “problems of sizing of dwellings and their divisions, starting by determining the needs and main functions to be met and respective requirements of articulation”.¹⁰⁰ At that time, given the inexistence in Portugal of research initiatives in the field of mental health, CHD’s researchers used thresholds established by Chombart de Lauwe in 1956 and some data of different European sets of laws.¹⁰¹ Thus, the threshold of satisfaction follows the scaling of total areas drawn up in 1949 by the *Union Internationale des Organismes Familiaux* (International Union of Family Organizations), known as the Cologne Rules.¹⁰² Accordingly, a table was filled to summarize proposed minimum areas, resulting from the sum of the space requirements by function. Consequently, given the similarities of this study with the one focused on family life

demands, under development by engineer Claude Lamure in CSTB,¹⁰³ this Parisian centre requested a copy of the Portuguese work from LNEC, confirming the relevance of scientific information exchange between LNEC and international research centres, even despite the very distinct political and social contexts of both countries.¹⁰⁴

One of the main goal of the urban housing survey was analysed later on the study titled *The use of space in housing*.¹⁰⁵ This work aimed at interpreting activities carried out in each unit of housing space. According to the researchers, “the data obtained was tabulated insignificant sets of activities (frequency of occurrence), formed by considering each activity as an inducer of other activities in the same space”.¹⁰⁶ In this study, observations focused on accounting for “the interpretation of sociological characteristics of defined types of use”.¹⁰⁷ This was informed by the interpretation of sociologist Maria Amélia Corrêa Gago, who worked for many years with Valente Pereira at LNEC.

Finally, problems associated with dwelling adaptation to family and individual needs, discussed in CHD’s previous studies, acquired a new dimension within the study *Rationalization of dwellings organization solutions*,¹⁰⁸ also closely related to the problems of urban planning. The need for an in-depth investigation about the future conditions of habitat was recognized worldwide at that time, particularly due to the increase of mobility and leisure time, and the unprecedented intensity of the urbanization phenomenon.¹⁰⁹ Thus, to seek urban space with greater quality, the geometric forms of buildings were studied at LNEC, following LUBFS’s studies, conducted by Leslie Martin and Lionel March (1934-2018).¹¹⁰ According to Costa Cabral, this study was a reference for the development of the urban plan and architectural project of cell C in South Olivais (1959-1968).¹¹¹

Our idea was that dwellings were not limited to the minimum areas but to an area that allowed several subdivisions. Our idea – that was applied in Olivais, by Portas and me, in our dwelling projects – was that the kitchen had to move to a central zone, because the kitchen is where the family get together, it is where the woman works when she comes from her outside work, it has to be the centre of the house.¹¹²

Design

The Housing Policy Colloquium (1969) alerted to the potential of evolutionary housing, as an alternative to models frequently used in Portuguese public residential neighbourhoods, particularly housing blocks. The research work conducted by Silva Dias and Portas, titled *Typologies of buildings. Evolutionary Housing*,¹¹³ proposed “to explain the characteristics of the program and to indicate appropriate typologies for its realization”.¹¹⁴ Published in *Arquitectura* journal, this study constitutes “a system based on simple rules of design execution, capable of ensuring a first stage of application, but designed in such a way that does not prevent the qualitative evolution of the house and of the divisions”.¹¹⁵ The primary concern was to follow the socio-cultural evolution of inhabitants. Thus, certain types of plots (narrow and long, square, and minimum) and a type of residence with evolutionary characteristics were studied. In other words, a “horizontal ‘compact group’, of individual houses with an increase of private free space still partially buildable” was sketched.¹¹⁶ The authors concluded that the evolutionary typology should correspond, in the city, to “high density with low height”,¹¹⁷ a theory which was directly applied by Silva Dias at Alto do Moinho neighborhood (1969-1976, Figure 6), and by Portas, Teotónio Pereira, João Paciência (born 1943) and Pedro Viana Botelho (born 1948) at the Restelo neighborhood (1970-1984, Figure 7).¹¹⁸

(please insert here figure 6)

Figure 6. Alto do Moinho schematic plan

Source: Portas, Nuno, and Mendes, Manuel. *Portugal architecture 1965-1990* (Paris, Editions du Moniteur, 1991): 64.

(please insert here figure 7)

Figure 7. Restelo urban plan

Source: AAVV, “‘Dossier’ Restelo” [Restelo folder], *Arquitetura* 130 (1974): 13

(please insert here figure 8)

Figure 8. Bartolomeu Costa Cabral, Francisco Silva Dias, Nuno Portas and Manuela Fazenda (top); Maria da Luz Valente Pereira, Alexandre Alves Costa, Gonçalo Byrne and Helena Roseta (bottom)

Source: Authors personal archive.

Discussion and Conclusions

Although Portugal was under a dictatorial regime, at the moment CHD was starting its research in architecture and urbanism (1961-1969), and later when substituted by the Architecture Division (1969-1979), LNEC researchers endeavoured their research with the support of works from analogous international research centres, namely in countries where no political and ideological repression was taking place. To identify research methodologies and techniques of investigation in use overseas, LNEC supported the cost of research, field trips and the acquisition of specialized books and scientific journals, which arrived around their time of publication and were considered essential to

promoting LNEC's researches (Table 2). As verified, despite the political context, LNEC's researchers gained at that time access to international bibliography, the opportunity to travel abroad and to establish contacts with foreign researchers and authors of worldwide reference.

(please insert here table 2)

Table 2. Timeline: The most representative participation on scientific meetings, field trips, publications, and acquisition of relevant books by LNEC's researches in architecture and urbanism (1960-1974)

Source: Authors

Given the sparse research experience of those young architects, for a more scientific approach to architecture and urban issues, beside the references from other international centres and researchers, Silva Dias pointed out that adopted methodologies were also identified "according to each one's intuition. This means that the method was to support an investigation step by step, making use of each one's previous experience".¹¹⁹

I did that research with the methodology with which I would make a project – there is the white paper anguish –, then the ideas are coming. Then there is that return of the paper to the eyes, from the eyes to the brain, from the brain to the hand, from the hand to the paper. The feeling I had was that I was doing a project, the method was the same.¹²⁰

Therefore, as the different working methods did not impose a linear path, we underline the strategic importance of the identification and combination of

methodological contributions from distinct disciplines. The social sciences were crucial to introduce research techniques based on surveys, which provided not only an evaluation centred on the selection of samples according to sociological criteria, but also to current architectural analysis and societal problems. Given the experimental character of such surveys, as mentioned by Valente Pereira, sometimes research could not guarantee the statistical validity of its conclusions.¹²¹

Every time I gained anything in the investigation, it was by being in contact with another discipline. First was sociology, it was particularly important for me to have an idea of how to define a subject so that an inquiry could be made. A survey, contrary to what many people think, does not teach us anything at all, nor does it confirm or refute hypotheses that we present, therefore, it is not, in a way, a research instrument.¹²²

The desire to obtain experience on computer representation in architecture research lead CHD methodologies to apply some methods proposed by engineers and mathematicians. From analytical research, based on observation of prototypes, and survey analysis, architects searched for numerical results to an automatic analysis. Yet, in search of a more objective process of project design, this kind of scientific analysis was not always straightforward in evaluating the quality of architecture, as noticed by Alves Costa.

The interest in studying social housing came from me. I had to do a questionnaire, to transform the questions into a binary answer – ‘yes’ or ‘no’ – to be able to introduce in a computer. It was [Eduardo Martins] Zuquete

[(engineer)] and Madalena Quirino [(mathematician)] who helped me because there were cases that were neither ‘yes’ or ‘no’, questions that did not come to the point. (...) The idea was to create a matrix that would work as a criterion for evaluating architectural projects. We applied more than 1000 questions and if the project answered a percentage of those, it meant that the solution was good. Portas was the one who invented all this – it did not occur to me. He wanted to establish a scientific criterion for evaluating the dwellings.¹²³

As verified, between 1961 to 1974, LNEC’s scope of interest shifted from the dwelling to the urban space. The developed lines of research searched for a more objective process of project design, essential to support the Portuguese government housing projects. On the one hand, outside the laboratory, some of LNEC’s researchers were also in charge for the proposal of some of Municipal social housing projects. For example, Costa Cabral and Silva Dias, which were also architects from the *Federação de Caixas de Previdência* (Federation of Pension Funds, c. 1960-1963) and from the *Gabinete Técnico da Habitação* (Technical Housing Office from Lisbon’s Municipality, 1960-1963), respectively, or Nuno Portas who become the State Secretary for Housing (1974-1975) and responsible for the beginning of SAAL’s (Ambulatory Service of Local Support) guidelines. On the other hand, the political positions of some of these researchers had inevitable consequences outside the laboratory. For instance, Silva Dias, for political reasons, was not allowed to head the Southern Regional Section of the Portuguese National Union of Architects.

Finally, interdisciplinarity was definitely a key characteristic marking developments in architecture and urbanism research at LNEC, between the early 1960s to the middle 1970s. Today, these continuing multidisciplinary and interdisciplinary approaches are

still considered fundamental for furthering the research in architecture and urbanism at LNEC, namely at the Urban and Territorial Studies Nucleus, the division where the fields of architecture, urbanism, and social sciences still exist, in articulation with sustainability issues. Furthermore, the discussion of more contemporary problematics, which affected the daily lives of urbanites, and the agendas of organizations directly engaged with controlling the construction of people's houses, were central both to the Portuguese research centre as well as for the International research centres. It was therefore the identification of the right questions and methods of approach that joined Portuguese and international researchers, despite their backgrounds in countries with different political contexts.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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¹ Decree Law n° 35.957 of November 19, 1946, *Diário do Governo*, I Série 263 (1946).

² Building Methods Studies Service, Structural Studies Service and Study and Testing of Materials Service.

³ Decree Law n° 43.825 of July 27, 1961, *Diário do Governo*, I Série 83 (1961).

⁴ Continued at the subsequent unit, the Architecture Division (1969-1979).

⁵ Maria Fernanda Rollo, Maria Inês Queiroz and Tiago Brandão, “Pensar e mandar fazer ciência. Princípios e pressupostos da criação da Junta de Educação Nacional na génese da política de organização científica do Estado Novo” [“To think and to order to do science. Principles and assumptions of the creation of the National Education Council in the genesis of the Estado Novo's scientific organization policy”], *Ler História* 61 (2011): 105-145; Tiago Brandão, “A emergência da Junta Nacional de Investigação Científica e Tecnológica (1967-1974): receção de um modelo e racionalidades tecnocratas” [“The emergence of the General Council of the National Board for

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⁸ Patrícia Bento d’Almeida, Teresa Marat-Mendes and Michel Toussaint, “The publication of the scientific contributions researched at LNEC in journals *Arquitectura, Binário* and *Técnica*”, *Cidades: Comunidades e Território* 39 (2019): 174-191.

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¹² Namely: 1) Costa Cabral - NTP office (1950 -1958); internship at *Centre Scientifique et Technique du Bâtiment* (CSTB, Paris, 1962) and at Greater London Council (1965); 2) Valente Pereira - NTP office (1957-1965); worked at *Société d’Etude Technique et d’Aménagement Planifié* and at the *Institut de Recherche et Formation en Vue du Développement Harmonisé* (Paris, 1962-1963); 3) Silva Dias - internship at CSTB

(1966); 4) António Reis Cabrita - NTP office (1966-?); 5) Gonçalo Byrne - NTP office (1968-?); 6) Manuela Fazenda - NTP office (1972-?); and 7) Helena Roseta - NTP office (1972-?). See Ana Tostões, *Arquitetura e Cidadania*, 317; Bartolomeu Costa Cabral, October 2, 2017 and October 10, 2018; Maria da Luz Valente Pereira, July 20, 2017 and November 7, 2018; Francisco Silva Dias August 20, 2017 and November 7, 2008; António Reis Cabrita, November 14, 2017; Manuela Fazenda, October 3, 2017.

¹³ Some of them being Progressive Catholics or belonging from the Catholic University Youth.

¹⁴ See for example: Kenny Cupers, “The expertise of participation: mass housing and urban planning in post-war France”, *Planning Perspectives* 68 (2014): 29-53; Klaus Junker, “Research under dictatorship: the German Archaeological Institute 1929–1945”, *Antiquity* 276 (1998): 282-292; and Avigail Sachs, “The Postwar Legacy of Architectural Research”, *Architecture Publications and Other Works* 62 (2009): 53-64.

¹⁵ Consider, for example: Ana Vaz Milheiro and João Afonso, *Nuno Portas, Prémio Sir Patrick Abercrombie UIA 2005* (Lisboa: Ordem dos Arquitectos and Caleidoscópio, 2005); Gil, Bruno. “Culturas de Investigação em Arquitetura. Linhas de Pensamento nos Centros de Investigação 1945-1974” [“Research cultures in architecture. Lines of thought in research centres 1945-1974”] (Master diss., University of Coimbra, 2012); Mariana Rodrigues de Carvalho, “Investigação em Arquitectura. O Contributo de Nuno Portas no LNEC 1963-1974” [“Research in Architecture. The Contribution of Nuno Portas at LNEC 1963-1974”] (Master diss., University of Coimbra, 2012); Nuno Grande, *O Ser Urbano nos Caminhos de Nuno Portas/The urban being: on the trails of Nuno Portas* (Guimarães: Imprensa Nacional Casa da Moeda, 2012); Tiago Lopes Dias, “Teoria e Desenho da Arquitetura em Portugal, 1956-1974: Nuno Portas e Pedro

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¹⁶ Nuno Portas: Lisbon School of Fine Arts (LSFA), 1964-1969; ii) Silva Dias: LSFA, 1967-1970; iii) Costa Cabral: LSFA, 1967-1969; and iv) Alves Costa: Porto School of Fine Arts, 1979-2010. See Gonçalo Canto Moniz, “O Ensino Moderno da Arquitetura. A Reforma de 57 e as Escolas de Belas-Artes em Portugal (1931-69)” [“The Modern Teaching of Architecture. The Reform of 57 and the Schools of Fine Arts in Portugal (1931-69)”] (PhD. diss., University of Coimbra, 2011).

¹⁷ Francisco Silva Dias, September 20, 2017.

¹⁸ Karel Teige, *The Minimum Dwelling* (Cambridge: MIT Press, 2002, 1st ed. 1932).

¹⁹ This through *Costruzione Razionale della Casa* [*Rational Construction of the House*] (1931) by Enrico Agostino Griffini (1887-1957), that arrived in Portugal in several copies and was used by many architects from the 1930s. In the presentation of the projects of the social dwellings of the Alvalade neighbourhood in Lisbon to the 1st National Congress of Architecture in 1948, by the architect Miguel Jacobetti, the references to the Alexander Klein method as published by Griffini are clear, as indicated in AAVV, *1º Congresso Nacional de Arquitectura: Relatório da comissão executiva, teses, conclusões e votos do congresso* [*1st National Congress of Architecture: Report of the executive committee, thesis, conclusions and votes of the congress*] (Lisboa: Sindicato Nacional dos Arquitectos, 1948): 263-286.

²⁰ Walter Gropius, “Construction horizontale, verticale ou de hauteur intermédiaire?” [“Horizontal, vertical or intermediate height construction ?”] in Lionel Richard (ed.) *Architecture et société* (Paris: Éditions du Linteau, 1995): 85-107.

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- ²¹ Ernest Neufert, *Arte de Projectar en Arquitectura* [*Architects Data*] (Barcelona: Gustavo Gili, 1942).
- ²² Mário Krüger, *Leslie Martin e a Escola de Cambridge* [*Leslie Martin and the Cambridge School*] (Coimbra: Faculdade de Ciências e Tecnologia da Universidade de Coimbra, 2005).
- ²³ Carvalho, “Investigação em Arquitectura”, 307.
- ²⁴ Christopher Alexander, *Notes on the Synthesis of Form* (Harvard: Harvard University Press, 1964).
- ²⁵ Serge Chermayeff and Christopher Alexander, *Community and Privacy* (New York: Doubleday, 1963).
- ²⁶ Christopher Alexander, “Uma cidade não é uma árvore” [“A city is not a tree”], *Arquitectura* 95 (1967): 22-29.
- ²⁷ Éric Lengereau, « Aux Origines de la Recherche Architecturale en France » [“The origins of architectural research in France”], in Jean-Louis Cohen (dir.) *L’Architecture entre pratique et connaissance scientifique* [*Architecture between practice and scientific knowledge*] (Paris: Editions du Patrimoine, Centre des Monuments Nationaux, 2018).
- ²⁸ Philippe Boudon, *Sur l'espace architecturale: Essai d'épistemologie de l'architecture* [*On the architectural space: Essay of architecture epistemology*] (Paris: Dunod, 1975).
- ²⁹ Philippe Panerai, Jean Castex and Jean Charles Depaule, *Formes urbaines: de l'îlot à la barre* [*Urban Forms: The death and the life of the urban block*] (Paris: Dunod, 1977).
- ³⁰ Francis Chassel (ed.), « Recherche Architecturale » [“Architectural research”], *Les cahiers de la recherche architecturale, Special Issue* 13 (1983).

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- ³¹ Francis Chassel, Introduction in : « Recherche Architecturale ».
- ³² AAVV, *La recherche en architecture – Un bilan international*. (Conference proceedings ‘Rencontres, Recherche, Architecture’, Marseille, Nancy, Nantes, Paris, 12-13-14 june 1984) (Marseille: Parenthèses, 1986).
- ³³ Kevin Lynch, *The image of the city* (Cambridge: Parenthèses, 1968); Edward T. Hall, *La dimension cache [The hidden dimension]* (Paris: Seuil, 1971, English 1st ed. 1966).
- ³⁴ Christian Norberg-Schulz, *Système logique de l’architecture [Intentions In Architecture]* (Bruxelles: Dessart & Mardaga, 1979, 1st ed. 1965).
- ³⁵ Decree Law n° 43.825.
- ³⁶ Maria da Luz Valente Pereira, July 24, 2017.
- ³⁷ José António Bandeirinha, *O Processo SAAL e a Arquitectura no 25 de Abril de 1974 [The SAAL Process and the architecture on April 25, 1974]* (Coimbra: Imprensa da Universidade, 2007).
- ³⁸ Ruy Gomes, *Planeamento de estudos no domínio dos edifícios: anos de 1969 – 1970 [Planning studies in the domain of buildings: 1969 - 1970]* (Lisboa: LNEC, 1969).
- ⁴⁰ Nuno Portas, *Estudos sobre habitação: relato sucinto dos contactos estabelecidos por ocasião do Congresso U.I.A. Paris 1965 [Housing studies: succinct report of the contacts established during the U.I.A. Congress Paris 1965]* (Lisboa: LNEC, 1965).
- ⁴² Nuno Portas and Ruy Gomes, *Inquérito-piloto sobre necessidades familiares em matéria de habitação. 1º Relatório: Programa, amostra e resultado da fase de inquirição [Pilot survey on family housing needs. 1st Report: Program, sample and result of the inquiry phase]* (Lisboa: LNEC, 1963).
- ⁴³ Carvalho, “Investigação em Arquitectura”, 295.
- ⁴⁴ José Vicente Milhano, *Rebate... Problemas sociais*. (Covilhã: [non identified, 194-]),
See Maria Luísa Alvim, *Livros Portugueses Proibidos no Regime Fascista:*

Bibliografia [Portuguese Books Prohibited in the Fascist Regime: Bibliography], (Braga: Faculdade de Letras da Universidade do Porto, 1992), accessed July 7, 2020, http://eprints.rclis.org/9342/1/livros_proibidos.pdf

- ⁴⁵ E. A. Lima Basto and Henrique de Barros, *Inquérito à Habitação Rural [Rural Housing Survey]* (Lisboa: n.i., 1942 and 1947).
- ⁴⁶ Sindicato Nacional dos Arquitectos, *Arquitectura Popular em Portugal [Popular Architecture in Portugal]* (Lisboa: Sind. Nac. dos Arquitectos, 1961).
- ⁴⁷ All reports were sign by: LNEC's Director, head of the Department; head of the Division; and, at last, the author(s).
- ⁴⁸ Maria da Luz Valente Pereira, July 20, 2017.
- ⁴⁹ Fazenda, which was member of this theatre group, was arrested as a political prisoner in 1973. Manuela Fazenda, October 3, 2017.
- ⁵⁰ Portas and Gomes, *Inquérito-piloto sobre necessidades familiares em matéria de habitação. 1º Relatório: Programa, amostra e resultado da fase de inquirição [Pilot survey on family housing needs. 1st Report: Program, sample and result of the inquiry phase]* (Lisboa: LNEC, 1963).
- ⁵¹ Such as: 1) housing acoustic requirements; 2) dwelling interior space; and 3) systematic compartmentalization processes. Gérard Blachère, *Savoir bâtir: Habitabilité, durabilité, économie des bâtiments [Know how to build: Habitability, sustainability, economy of buildings]* (Paris: Eyrolles Issoudun, 1966).
- ⁵³ Portas, *Estudos sobre habitação*, 4.
- ⁵⁴ Portas and Gomes, *Inquérito-piloto*, 14.
- ⁵⁶ Baptism godfather of one of his sons (Paulo).
- ⁵⁷ *Ibid*, 34.

⁵⁸ Namely: 1) Oslo (1942-1944, Odd Brochmann); 2) Great Britain (1942, J. Murray, Advertising Service Guild; 1950, G. P. Crowden, Royal Sanitary Institute; 1954, Dennis Chapmann, Liverpool University; no date, R. G. Bateson; 1955, Council of Scientific Management); 3) France (1946, A. Sauvy, *Institut National d'Études Démographiques*; 1952, Lafon-Michoud; 1954-1961, P. Chombart de Lauwe, Couvreur, etc. GES/CSTB; 1956, A. Meister, C.O.L. Cooperative; 1958, R. M. Casablanca); 4) Poland (1949-1958, A. Andrejewsky, IBM); 5) Sweden (1954, Lennart Holm, Home Research Institute); 6) Holland (1953-1955, *Comité Central du Longement – Bowcentrum*; 1955, C. Bitter, Weeren, TNO - Netherlands Organisation); 7) Portugal (1954, Nuno Teotónio Pereira); 8) Italy (1955-1958, Salvatore Alberti, INA–Casa; 1957, Mario Coppa); 9) Switzerland (1956, H. Zahner; 1960, J. P. Vouga); 10) Austria (1956, Rosen Mayer); 11) Czechoslovakia (1959-1960, Librova, Klofac *SNTL*); and 12); Denmark (1956, G. Mayer, *Statens Biggeforsnings Institut*). See Portas and Gomes, *Inquérito-piloto*.

⁵⁹ Nuno Portas, “Habitação Social: proposta para a metodologia da sua arquitectura” [“Social Housing: proposal for the methodology of its architecture”] (Architecture Final Thesis, Escola Superior de Belas Artes do Porto, 1959).

⁶⁰ Paul-Henry Chombart de Lauwe, “Sociologia da Habitação. Métodos e Perspectivas da investigação” [“Housing Sociology. Methods and Perspectives of Research”], *Arquitectura* 68 (1960): 41-50.3

⁶¹ Portas, *Estudos sobre habitação*, 9.

⁶² Manuel Rocha, *Relatório sumário da actividade do Laboratório Nacional de Engenharia Civil em 1972* [Summary report on the activity of the National Laboratory for Civil Engineering in 1972] (Lisboa: LNEC, 1972): 67.

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- ⁶³ Maria da Luz Valente Pereira and Nuno Portas, *Inquérito à habitação urbana. Objectivos gerais do inquérito* [Survey on urban housing. General objectives of the survey] (Lisboa: LNEC, 1967).
- ⁶⁴ *Ibid*, 1.
- ⁶⁵ Maria da Luz Valente Pereira, *Organização e qualidade do espaço urbano: Inquérito Piloto à utilização da cidade* [Organization and quality of urban space: pilot survey on the use of the city] (Lisboa: LNEC, 1971).
- ⁶⁶ Jay Wright Forrester, *Urban Dynamics* (Cambridge: M.I.T. Press, 1969).
- ⁶⁷ Maria da Luz Valente Pereira, *Modelo de análise dinâmica de uma zona urbana* [Dynamic analysis model of an urban area] (Lisboa: LNEC, 1970): 2.
- ⁶⁸ Maria da Luz Valente Pereira, *Organização e qualidade do espaço urbano: Modelo de análise dinâmica do sistema urbano à escala de zona urbana* [Organization and quality of urban space: Model of dynamic analysis of the urban system at the scale of the urban area] (Lisboa: LNEC, 1971): 60.
- ⁷⁰ Pereira, *Organização e qualidade do espaço urbano: Inquérito Piloto*, 31.
- ⁷¹ *Ibid*, 17.
- ⁷² Maria da Luz Valente Pereira, *Problemática dos Inquéritos à Habitação Urbana* [Urban housing surveys problematic] (Lisboa: LNEC, 1970).
- ⁷³ Maria da Luz Valente Pereira, July 20, 2017.
- ⁷⁶ Alexandre Alves Costa and Nuno Portas, *Racionalização de soluções da habitação: Análise e selecção de esquemas do fogo* [Rationalization of housing solutions: Analysis and selection of dwelling schemes] (Lisboa: LNEC, 1966).
- ⁷⁸ Consider the bibliography of Nuno Portas and Ruy Gomes, *Estudo das funções e da exigência de áreas da habitação. Necessidades familiares e áreas da habitação: Análise de exigências por funções da habitação* [Study of the functions and

requirements of housing areas. Family needs and housing areas: Analysis of requirements by housing functions] (Lisboa: LNEC, 1964).

⁷⁹ *Ibid*, 1.

⁸⁰ Provided by LNEC's first electronic computer, an "IBM 602-A" installed in 1957. LNEC, "Museu Virtual: Informática" ["Virtual Museum: Informatics"], accessed March 26, 2019, <http://www-ext.lnec.pt/LNEC/museuvirtual/>.

⁸¹ Namely: 1) Sleeping, rest of staff; 2) Food: meal preparation; 3) Food: current meals; 4) Food: special meals; 5) Living/Meeting area: family free time; 6) Being-Receiving; 7) Specific Activities: children's playground; 8) Specific Activities: youth study; 9) Specific Activities: adult work; 10) Clothing Treatment; 11) Laundry Treatment: washing; 12) Clothing Treatment: Drying; 13) Personal Hygiene; 14) Staying in the outdoor; 15) Separation: zones communication; 16) Interior Storage.

⁸² Luís Urbano, "Interview with Nuno Portas", in Luís Urbano (ed.) *Circa 1963: Conversas com arquitetos e cineastas* (Porto: AMDJAC, 2018): 52.

⁸⁴ Alexandre Alves Costa, July 20, 2018.

⁸⁵ Luís Moniz Pereira, Luís Monteiro and Nuno Portas, *Agrupamento de espaços a partir de grafos de adjacências [Grouping of spaces from contiguity graphs]* (Lisboa: LNEC, 1972).

⁸⁶ *Ibid*, 3.

⁸⁷ Namely Philip Steadman, *The automatic generation of minimum-standard house plans*. Working Paper 23 (Cambridge: University of Cambridge, Centre for Land Use and Built Form Studies, 1970); Bruno Gil, *Culturas de Investigação em Arquitetura*.

⁸⁸ Luís Moniz Pereira, Luís Monteiro and Nuno Portas, *Agrupamento de espaços a partir de grafos de adjacências*, 5.

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- ⁸⁹ Nuno Portas, *Implementação dum modelo urbano para a Área Metropolitana de Lisboa* [*Implementation of an urban model for Lisbon Metropolitan Area*] (Lisboa: LNEC, 1974).
- ⁹⁰ *Ibid*, 2.
- ⁹⁹ Portas and Gomes, *Estudo das funções e da exigência de áreas da habitação*; Nuno Portas, “Desenho e apropriação do espaço da Habitação” [“Design and appropriation of the housing space”], *Arquitectura* 103 (1969): 124-128.
- ¹⁰⁰ Portas and Gomes, *Estudo das funções e da exigência de áreas da habitação*, 1.
- ¹⁰¹ Namely from France, Italy, Belgium, Federal Germany, England, Netherlands, and Spain. *Ibid*, 30-33.
- ¹⁰² *Ibid*, 35.
- ¹⁰³ Claude Lamure, *Adaptation du logement à la vie familiale* [Housing adapting to family life] (Paris: Eyrolles, 1976).
- ¹⁰⁴ Portas, *Estudos sobre habitação*, 5.
- ¹⁰⁵ Maria da Luz Valente Pereira and Maria Amélia Correia Gago, *O uso do espaço na habitação* [*The use of space in housing*] (Lisboa: LNEC, 1974).
- ¹⁰⁶ *Ibid*, 3.
- ¹⁰⁷ *Ibid*, 6.
- ¹⁰⁸ Bartolomeu Costa Cabral, *Racionalização de soluções de organização de fogos: Formas de agrupamentos da habitação* [*Rationalization of dwellings organization solutions: Forms of housing clusters*] (Lisboa: LNEC, 1968).
- ¹⁰⁹ *Ibid*, 2.
- ¹¹⁰ Leslie Martin and Lionel March, *Urban Space and Structures* (Cambridge: Cambridge University Press, 1975).
- ¹¹¹ Bartolomeu da Costa Cabral, October 10, 2018.

¹¹² *Ibid.*

¹¹³ Francisco Silva Dias and Nuno Portas, *Tipologias de edifícios. Habitação Evolutiva: Princípios e critérios de projectos* [*Typologies of buildings. Evolutionary Housing: Principles and projects criteria*] (Lisboa: LNEC, 1971).

¹¹⁴ *Ibid.*, 1.

¹¹⁵ Francisco Silva Dias and Nuno Portas, “Habitação evolutiva. Princípios e critérios de projectos” [“Evolutionary housing. Principles and projects criteria”], *Arquitectura* 126 (1972): 2.

¹¹⁶ *Ibid.*, 4.

¹¹⁷ Dias and Portas, *Tipologias de edifícios*, 3.

¹¹⁸ José António Bandeirinha, *O Processo SAAL e a Arquitectura no 25 de Abril de 1974*; Patrícia Bento d’Almeida, *Bairro(s) do Restelo. Panorama Urbanístico e Arquitectónico* [*Restelo neighborhood. Urban and Architectural Panorama*] (Casal de Cambra, Caleidoscópio, 2015).

¹¹⁹ Francisco Silva Dias, August 20, 2017.

¹²⁰ Francisco Silva Dias, August 20, 2017.

¹²¹ Pereira, *Organização e qualidade do espaço urbano: Inquérito Piloto*, 60.

¹²² Maria da Luz Valente Pereira, November 7, 2018.

¹²³ Alexandre Alves Costa, July 20, 2018.