Título: **Usability test and implications of an activity allocation mapping in complex organizations: perceptions about a software by emergency room agents**

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Revista: Archnet-IJAR: International Journal of Architectural Research
DOI: 10.1108/ARCH-11-2023-0301
Aceito em: 13 de fevereiro de 2024
Publiado em: 18 de março de 2024

Link: https://www.emerald.com/insight/content/doi/10.1108/ARCH-11-2023-0301/full/html?skipTracking=true

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| Journal: | *Archnet-IJAR: International Journal of Architectural Research* |
| Manuscript ID | ARCH-11-2023-0301.R2 |
| Manuscript Type: | Research Paper |
| Keywords: | Usability testing, Building Environment Software, Organizational Mapping, Multi-Domain Matrix, Dependency Structure Matrix, Post-Occupancy Evaluation |
| | |

# Usability test and implications of an activity allocation mapping in complex organizations: perceptions about a software by emergency room' agents


## Abstract

**Purpose**: Properly allocating an organization's activities within a building is vital to reducing the relational complexity arising from process-environment interactions. Multiple relationships are mapped, and certain interferences are only identified after these have been processed. The method/software employed for this task is Mapping Activity Environment Allocation (MAEA). However, data input and interpretation of results depend on the usability conditions of the organization's agents. This paper presents MAEA's usability test results. **Methodology**: Test sessions and interviews were carried out with seven agents registered at a University Hospital. Participants were instructed to think aloud during its use, and immediately afterward, responded to semi-structured interviews. Test sessions were audio recorded and screen captured. **Findings:** Participants found the software easy to use and pointed out valuable implications for professional and academic use. In addition to relationship, priority, and parallelism data, customized visualizations were created, including organizational charts, flowcharts, and activity flow routes on the floor plan. **Originality:** The ability to map the allocation of activity-spaces in the pre-design phase of building architecture allows for early identification of interactions, aiding in the development of more robust project requirements during programming. **Practical implications:** MAEA's simplicity allows non-designers to conduct evidence-based assessments and decisions. It allows designers to test their proposals during the programming and outline proposal stages. **Social implications:** A more detailed definition of design requirements from the beginning increases the conditions to successfully achieve project goals.



**Keywords:** Usability testing; Building Environment Software; Organizational Mapping; Multi-Domain Matrix; MDM; Dependency Structure Matrix; DSM; Post-Occupancy Evaluation; POE; Pre-Design Evaluation; PDE.

**Classification**: Research paper.


## 1 INTRODUCTION. THE SPACE ALLOCATION PROBLEM

Work organizations that involve the interaction among various roles, activities, and environments exhibit a significant relational complexity that must be considered in order to attain levels of efficiency and effectiveness (Bolton *et al.*, 2021). Consequently, current research on organizations continues to emphasize that work environments play an essential role in how people interact, identify themselves, and fulfill their roles (Baldry, 1999; Leone, 2023). Although post-occupancy evaluations (POEs) of relevant cases provide valuable information into the functional, technical, and behavioral aspects of building use, and the experiences of design and facility management professionals are essential for understanding and addressing such relationships, the number of relationships exceeds what can be captured by human perception (Pereira and Ornstein, 2023a; Salaheldin *et al.*, 2021). Therefore, technically oriented research tools to assist in identifying such relationships are crucial complementary means to achieve design quality (Salama, 2019). Mapping the allocation of activities within the Built Environment spaces is a method used to obtain strong, measurable, and verifiable evidence to support decision-making in the early stages of workspace design.

Research addressing the Space Allocation Problem (SAP) traditionally had a spatial focus, primarily aimed at the geometric resolution of building floor plans and cost estimation (Dorrah and Marzouk, 2021; Liggett and Mitchell, 1981; Rahbar *et al.*, 2019). From this perspective, the evaluation of a layout is the best find solution according to the architect's subjective and objective values (Rahbar *et al.*, 2019). The outcomes of SAP research have progressed in parallel with the implementation of typical Computer-Aided Design (CAD) and Building Information Modeling (BIM) software. It focuses on automation to generate design solutions based on specific optimization parameters (Calixto and Celani, 2015; Saha et al., 2020). Such approaches are suitable for intermediate or advanced stages of design conception because they assume that spatial relationships – such as dimensions, boundaries, openings points – and organizational relationships – linked to roles and activities – are already well-defined (Ezzeldin *et al.*, 2021; Morgareidge *et al.*, 2014; Shin *et al.*, 2017). In other words, the relationship between activities and spaces to define the building environments is a validated input for the development of space-related parameters.

Mapping Activity Environment Allocation (MAEA) is an object-oriented programming-based method that allows identifying and evaluating relationships between activities and spaces within an organization in an existing or planned environment. In the case of existing environments, it enables recognizing limitations in the existing spatial arrangement used by the organization. This information can be utilized by facility managers and architects to decide what type of intervention may be necessary if any allocation issues are identified. In the case of planned environments, it provides a predictive evaluation of spatial arrangement performance, even during the definition stage of the requirements program (Pereira, Ornstein, Soares, *et al.*, 2023). This paper presents user perceptions captured during usability testing and interviews regarding their understanding of this method, how they use it, whether it meets their expectations, and its impact on their work organization.

### 1.1 An Analytical Model-Based Approach

A mathematical approach is necessary to map the relationships between environments and activities within an organization before representing the spaces, one that unifies all elements that will be related, such as a graph. Simulation models commonly developed in CAD, BIM, or SAP relies on the availability of a set of input data, and detailed performance metrics sufficient to meet simulation conditions (Morgareidge *et al.*, 2014, Vanbrabant, Braekers, *et al.*, 2019; Vanbrabant, Martin, *et al.*, 2019). In contrast, analytical models can be designed to determine relationships with a reduced set of input data. With a set of simple and efficient mathematical equations, it is possible to model deterministic and stochastic, as well as dynamic systems (Vanbrabant, Braekers, et al., 2019). This feature can be leveraged in specific contexts of information scarcity, allowing the anticipation of the analysis to a stage prior to spatial development (Pereira, Ornstein, Soares, *et al.*, 2023).

A strategy used to develop complex systems is the Dependency Structure Matrix (DSM), also referred to as the Design Structure Matrix (Browning, 2016; Cao *et al.*, 2018; Eppinger and Browning, 2012; Senthilkumar and Varghese, 2009; Sinha *et al.*, 2012). Due to its lightweight and adaptability to various volumes of data, DSM has demonstrated significant results in the relationship between the product, production, and organization (Eppinger and Browning, 2012; Lee *et al.*, 2010; Reichardt *et al.*, 2012; Sinha *et al.*, 2012). It has also been used in the field of Architecture, Engineering, Construction, and Operation (AECO) to manage information complexity, risk, sustainability, and more (Akintola *et al.*, 2015; Cao *et al.*, 2018; Pektaş and Pultar, 2006; Schmidt *et al.*, 2014). With DSM, it is possible to map dependencies between entities in the same system, whether be it product, environment, or process, to manage their relational complexity (Browning, 2016; Unger and Eppinger, 2011).

The few DSM studies found that investigate the organization of the built environment, or AECO, employ a combination of Multi-Domain Matrix (MDM); however, none of these studies has used it for activity allocation in spaces (Hickethier *et al.*, 2011; Pereira, 2019; Reichardt *et al.*, 2012). MDM is a multidimensional matrix that allows for the combination of different domains, such as components, functions, and system parameters, revealing their dependencies (Eppinger and Browning, 2012; Schmidt *et al.*, 2014; Sosa, 2007). By combining DSMs, an MDM provides a comprehensive view of the domains in a system and their interdependencies (Wilschut *et al.*, 2018). In the case of the tested method, the domains are the items that make up the organization's process and environment, and the dependency is the allocation of activities within spaces.

## 1.2 Previous Results of Spatial Activities Allocation

In this paper, the discussion presents a direct evolution to developing the activity allocation method in the built environment and the MAEA tool, which supports its application. After demonstrating the main functionalities of the method/software (Pereira, Ornstein, Soares, *et al.*, 2023), when the processing scripts were published (Pereira and Amaro, 2023), it carried out the report results of the InfoVis discussion workshop with designers (Pereira, Ornstein and Velloso, 2023), discussing how it conducted the analysis of the results based on the real case study (Pereira and Ornstein, 2023b), the improvements implemented to the method/software and user interface. It is this version that was subjected to usability testing.

## 1.3 Objective

The usability test evaluated the software's usability conditions for users to [a] determine if users comprehend the method and if it meets their needs, [b] observe how users utilize the software, [c] discover new features for the system developed (method/software), and [d] outline its organizational scope.

## 2 RESEARCH METHOD

Software usability tests are part of the research carried out in Human-Computer Interaction (HCI). It investigates the communication between computer systems and individuals in order to make the former more practical, efficient, and user-friendly (Goodman *et al.*, 2003; Zhang and Adipat, 2005). Usability tests in HCI typically consider attributes such as learnability, efficiency, memorability, errors, satisfaction, effectiveness, simplicity, comprehensibility, learning performance (Zhang and Adipat, 2005).

The Usability Testing Framework comprises five fundamental stages: preparation, data collection, data extraction, analysis, and communication of the obtained results (Balagtas-Fernandez and Hussmann, 2009). The planning of these stages can employ quantitative approaches, involving the observation of patterns in numerical variables linked to the frequency of events and task duration. These low-level details are extracted through automated log resources (e.g., error logs, clicks, task times, button clicks, navigation route), gathered in sufficient quantity for statistical analysis. Other approaches based on qualitative means are primarily utilized to recognize attributes of satisfaction and comprehensibility, as they provide high-level information (Balagtas-Fernandez and Hussmann, 2009; Diah *et al.*, 2010).

Aspects related to errors and navigation performance adjustments were resolved in a pre-test. Any remaining bugs were documented and addressed. However, as the research aimed to identify users' perceptions regarding the utility and usability conditions of MAEA, it adopts a qualitative approach. Two specific and complementary procedures were adopted: observation and interview.

The following sections outline test and interview preparation, data collection, and analysis of the findings.

This study was conducted by the Declaration of Helsinki and approved by the research ethics committee of the University Hospital of the University of São Paulo (CEP/HU/USP) (protocol code CAAE: 44679021.0.0000.0076, approved on 26/03/2021).

### 2.1 Participant definition

A relevant aspect of the preparation is defining the ‘user,’ which may correspond to a significant sample of the user population or determined by a condition of expertise. The tested software was developed, and its functionality was demonstrated (Pereira, Ornstein, Soares, *et al.*, 2023) based on data collected from 13 specialists working at the *Hospital Universitário da Universidade de São Paulo* (HUUSP), São Paulo, Brazil. To carry out the test, 7 of these professionals were selected, which included different genders, training, and areas of activity at the institution (Table I).

*Table I – Duration of Tests and Interviews.*
*Fonts: authors.*

These roles are involved in activities with greater interaction for the operation of the emergency department (ED). In contrast to an Intensive Care Unit (ICU), where patients and their companions remain for long periods, emergency departments are characterized by a rapid and intense flow of activities and interactions (Ferri *et al.*, 2015; Soares *et al.*, 2024). Thus, while the quality and dimensions of the space are always important, observe that the allocation and flow of activities within ED spaces become critical. Such demand guided the definition of the occupation type to test the software operations related to the mapping of objective relationships between the process domain and the environment. Each participant was observed while testing the software and subsequently responded to a semi-structured interview. The tests and interviews took place in person, anonymously and had varying durations, ranging from 31 to 66 minutes in total. (Table I).

## 2.2 Scripts and Applications of the Usability Test and Semi-Structured Interview

The usability test was planned in 6 steps. The usability test guidance protocol (Table II) contains the necessary information to conduct the test.

*Table II - Usability Test Script.*
*Fonts: authors.*

The 'Usability Test Script' consists of two parts: the first part is a test script that outlines the steps the participant should follow, and the second part is a guide listing points of attention for the researcher to facilitate the test together with the participant. During the tests, the researcher guided the participant in performing the planned operations, clarified doubts, and recorded personal observations or verbalizations made by the participant. Participants were instructed to engage in simultaneous think-aloud while using the software (Fan *et al.*, 2019; Zhao *et al.*, 2014). After the explanation of the test sequence, which took 8 to 10 minutes, participants operated the software freely to achieve the objectives.

The interviews conducted after the test followed the interview script (Table III), designed to support the diagnosis based on the perspective of expert users. It is a semi-structured interview consisting of five open-ended questions, with a focus on the test. Participant and anonymous professional characterization questions had already been conducted in a previous stage before software development.

*Table III - Semi-Structured Interview Script: Instrument Diagnosis.*
*Fonts: authors.*

The collected data were processed and extracted for analysis in various ways, such as computer screen recordings and audio recordings of the tests and interviews. The researchers transcribed and summarized the arguments presented by the interviewees based on this material. This served as the primary material for the subsequent analysis and discussion. Two additional sources of evidence included the researcher's notes when administering the test and mouse and keyboard movements recorded on the computer screen

recording during the tests. These sources supplemented the analysis of the interviews, providing insights into non-verbalized information by the participants.

## 3 FINDINGS

An initial expectation for the usability test was to ascertain whether the professionals at HUUSP would be able to operate the software for updating (complementing and revising) data regarding the allocation of activities in the ED and recording the usage and participant feedback from individuals with different professional profiles to determine if using it required any specific skills. It was observed that a basic computer literacy level was sufficient. For instance, one participant reported using only mobile applications (cell phone) and quickly mastered navigation and editing commands within the first 10 minutes of the test.

As participants manipulated the software's features and engaged in dialogue with the researcher, they made observations and subsequently adjusted, subtractions, or additions to the data that was already available. They demonstrated understanding how to perform the key operations required to successfully populate the database. Additionally, they critically reviewed relationships within their organizational sectors. On the other hand, the participants were unable to perform more advanced operations related to the analysis of relationships between organizational roles in different sectors. The Role 1 and Role 2 mentioned this point, noting they would require more time and access to consult other professionals.

Beyond the evaluation of satisfaction and usage conditions of MAEA, another set of information was collected to guide software enhancements and form a diagnosis of errors and improvement opportunities. The current report does not address this diagnosis because it is residual occurrences from the pre-test, and findings consist of an extensive list of errors and minor adjustments, of specific interest to the implementation stage rather than use. However, exceptionally, a specific item related to navigability that remained unresolved in the pre-test was added to the current test. Although it is not part of the set of evidence collected in the interview, the research team wanted to confirm which layout option would be better accepted by users (

Figure I).

*Figure I – default layout [a] with vertical reading, and alternative layout [b] with mixed vertical and horizontal reading*
*Fonts: authors*

To test which layout is better, the software version they used had a default layout for the data management pages, represented by of the organization page (

Figure I a), and an alternative layout to process page (

Figure I b). In the default layout, the relationship lists and their buttons were organized in columns, while in the alternative layout, are horizontally arranged. Analysis of voice and screen recordings revealed

that in alternative template (option b) the mouse was lost, and participants hesitated when operating, expressing doubt. The default template (option a), as it always uses vertical guidance, made it unnecessary to click on the buttons corresponding to each field. This result led to standardize all data management pages for the organization, process, and environment domains with a column layout.

### 3.1 Reports on Using the Program

The evidence gathered and synthesized in Table IV provides the basis for the diagnosis conducted in the following section. The themes were organized based on the responses, employed as the primary source of the survey, and supplemented with the researcher's annotations made during the tests.

*Table IV - Summary of interview responses after testing.*
*Fonts: authors*

The semi-structured interview, consisting of five questions, allowed guiding participants' responses to specific aspects related to its use, data input and output representation quality, occurrences of operational issues during use, perspectives related to using it in their professional and academic activities, and a final open-ended question, intended to capture any information not covered by the previous questions but deemed relevant by the participants. Participants freely responded to each question, as summarized in Table IV.

## 4 RESULTS AND DISCUSSION

Throughout the analysis of the responses, they were classified into four general themes, addressing the perception of the software's utility in professional and academic activities, the need to develop user guidance, interface-related issues, improvements in data input management, and suggestions to view results.

### 4.1 User Perception. Conditions of Use in an Organization

Participants who used the software indicated they were satisfied with the initial usage experience. Predominantly, they recognized the importance of recording information to guide facility and process management activities. The ability to relate processes to the spaces accommodating them was seen as generally important (role 3, role 4), but particularly due to the demand for adapting the built environment. *This is especially crucial during renovations when there is a need to segment and isolate a space without disrupting healthcare activities* (role 2).

In this regard, roles 2 and 4 emphasized the relevance of the results for a real situation they were involved in, where a renovation project of the ED and outpatient facilities had been initiated to improve healthcare conditions. In particular, the Role 4 believes it is important to confirm whether *the proposed arrangement meets the demands and does not repeat problems of the existing spatial layout*. Part of the organizational arrangement, but more specifically the ED processes, had been adapted to an existing environmental layout

to overcome any unfavorable operational conditions resulting from the physical and spatial inadequacies of the available facilities. Without mapping and subsequent critical analysis and reorganization of the processes, such idiosyncrasies can be carried over to a newly designed arrangement, perpetuating practices that only exist to overcome difficulties that can be addressed through proper design.

In addition to the benefits in renovation projects or new installations, the perspective of *'aligning' process and environment* (role 3), that is, mapping the organizational congruence presented, offers *the possibility to assess and direct the activities of each role towards the other roles* (role 3) from a less commonly used but enlightening perspective in order to *understand the dynamics of service operation* (role 4). Participants noted that such a perspective provides additional gains, as indicated below:

Role 1 emphasized that, *in addition to its intended use, they believe the results serve educational purposes in learning professional practice, especially in a university hospital and particularly in their department*. Indeed, in sectors like food and nutrition, the logistics related to the flow of information, resources, and people is an important service aspect. Despite notable advancements in communication and informatics, part of this flow is directly influenced by traffic conditions within the facilities in which it occurs. This delineates knowledge about flow operations as an area of interest for the professionals learning experience, those who work in these fields.

Roles 2, 5, and 6 identified the potential use of workflow distribution within the existing environments for managing the operations of cleaning and laundry services. This is particularly relevant during occasional changes in the collection of different types of waste and used clothing due to exceptional but recurring situations involving the isolation of areas for maintenance, repair, etc. Such practical gains in managing the operations of complementary services within the HUUSP facilities through flowcharts were also highlighted by Role 2, especially related to interactions between Engineering and Maintenance services and cleaning services.

Roles 6 and 7 attached importance to the managerial and strategic perspective of mapping, suggesting that *mapping allows to better utilize staff, justifies personnel hiring, redirects investments, and reduces waste* (Role 7). However, this perspective relies on institutional legitimization because there is *a path* (between its application and the resulting benefits) *that needs to be embraced by the organization to be effectively used in operational improvements and management* (Role 6).

The analyses presented in this section were collected during interviews and are based on the particular user experience of each participant regarding their first contact with the organizational congruence mapping system between processes and the built environment.

The analyses presented in this section were gathered during interviews and are based on the user experience of each participant regarding their first contact with the organizational congruence mapping system between processes and the built environment. These impressions predate the extensive use of the organization's method/software and should be understood as follows: They represent the perspectives of qualified professionals with practical experience in their respective fields who have assessed the potential benefits and challenges of use in organizations with complex service structures like hospitals. These analytics do not represent any commitment or official perspective of the institution in which they work, nor do they represent personal judgments on their own or other involved roles.

### 4.2 Users' support: coach and guidelines.

Participants expressed the software was easy to use and attributed this to the assistance provided by the researcher responsible for the test (Roles 1, 2, 6). Considering it was the first time using it and for a short period, Role 3 considered the result to be good. Role 1 pointed out the importance of developing a user instruction manual, and Role 6 specified the need for "a tutorial that clarifies the logic of operation between set, entity, and relationship; once the logic of the method is understood, "the use will be intuitive." The method's structure is, therefore, an introductory part of its use. This relationship is partially indicated on the program's homepage and should be complemented by a tutorial before explaining how to perform the operations.

Another user support material guidance based on the interviews relates to communicating through an invitation to experiment the system. Role 4, for instance, expressed doubt whether he would be able to perform the operations without the researcher's support during the test and could not say whether a manual or instructional or tutorial video would be sufficient resources, as she/he does not usually use a PC in her/his professional activities or personal life. However, it is worth noting that this participant demonstrated performance like the other participants and was able to fulfill all the functions outlined in the test.

Despite this observation and being the only case of uncertainty regarding the adequacy of a manual/tutorial/user guide, a recommendation for the application of the method in future research involves combining existing guidelines with a previous and introductory and previous workshop. Choosing an introductory workshop for using the method aligns with the observations of the interviewees, who indicated that any difficulties could be overcome through practice (Role 3, 5, 6). This "hands-on time with the program to input work data" will not only help overcome such difficulties but also provide conditions for "more constructive, informed, and detailed criticism of its use" (Role 5).

### 4.3 Data management interface and logic

The suggestion to include the method's structure on the homepage is part of the effort to make transparent to the user what relationships are established and what input data is required (Figure II). This arrangement

initially resulted in a somewhat cluttered interface for Role 3 but quickly proved to be ‘well-structured’. One interviewee commented that after understanding the structure, it was easy to operate. While the test script (Table II) suggests a linear activity, in practice, it was applied iteratively, involving cycles of data management and processing. During step 6, when participants click the 'prosecute' button (Figure II), an initial script verifies the integrity of the data and identifies the absence of necessary relationships for analysis. This information assisted users in reviewing their work.

*Figure II – home page*
*Source: authors.*

Role 5 found it easy to use because she could relate items of organization, processes, and the environment already entered in any of the system windows (Figure III). For example, once role and activity data were entered, they could freely relate them in both the organization and process windows. Such data consistency provides the perception of transparency and reliability of the integrated database recording system.

*Figure III – data management page example*
*Source: authors.*

Specifically, regarding the process window, Role 5 emphasized the importance of considering the timing and periodicity of activities and felt the need to be able to input subprocesses within the inserted processes (Figure IV). The conditions for subdividing processes into subprocesses or compartmentalizing activities into steps were not foreseen in the method, as these arrangements are artificial. In other words, the congruence logic recognizes that work can indeed be described in independent, sequential, and parallel activities that are related due to their interdependence in achieving results. Organizing these activities into processes is a consequence of strong interdependence. This arrangement is consistent with the condition of organizational modularity (Sanchez and Mahoney, 1996; Sosa *et al.*, 2000; Voordijk *et al.*, 2006). However, it is often seen that organizational practice institutionally groups a set of activities into subprocesses and departments without addressing this modularity condition. An alternative use approach was proposed to reconcile the logical condition for the method's operation and this institutional demand, using the resource of relating the same activity to more than one process (Figure IV).

*Figure IV – process page*
*Source: authors.*

The condition of multiple relationships between sets and entities allows composing different organizational arrangements ($O_{rn}$), such as functional, matrix, and project-oriented systems (Figure V). Role 7 emphasized this modeling freedom of relationships, expressing it is a "positive aspect" that the software exhibited "good linear reasoning of the method's process" and offered "the existing possibility to customize the data organization structure." The freedom to organize the data, combined with processing relationships

only at the entity level, primarily empowers the manager to map the organization as is. During processing, they can identify strong relationships and reorganize subprocesses, teams, and departments, thus formulating an outcome-oriented organizational architecture ($P_{aa}$). This step is independent of activity allocation in the environment ($A_{sa}$) but theoretically it provides the organization with better conditions to achieve the expected outcome (Figure V).

*Figure V – usage procedure scheme*
*Source: authors*

The analysis of the InfoVis results that follows reveals, among other things, how to use the visualization process identified during the InfoVis workshop (Pereira, Ornstein and Velloso, 2023) and the tests in order to support the definition of a workspace arrangement ($E_{ss}$) for the improved allocation of activities within the spaces ($A_{sa}$).

## 4.4 InfoVis Results

Data visualization was an aspect of the development method in which initial tests showed the need for significant improvements. The way information is visualized, based on DSM and MDM, is not intuitively and quickly interpretable (Figure VI**Error! Reference source not found.**). It involves visualizing complex, multidirectional relationships, thus implying a non-linear reading of a matrix and supplementary reading between the process matrices, the environment, and the relationship between entities in these two domains.

*Figure VI – matrixial mapping environmental and processual congruence*
*Source: authors, based in Pereira, Ornstein, Soares, et al (2023).*

This initial reading difficulty was reflected in the participants' responses. Role 6 and 7 commented that the matrices are difficult to understand as understanding is not intuitive, requiring reading instructions and training. Role 5 corroborates the difficulty in understanding the results due to the volume of information involved. For them, a way to simplify and guide visualizations is to highlight the links that have been influenced by a selected environment, role, or activity, and to emphasize 'key points' for 'anchoring' the reading, even if this leaves some relationships in the background. Determining these points is crucial for understanding the results.

In this context, role 4 mentioned that understanding 'the relationships between the process and the environment' observed in the matrices would be enhanced if they were combined with lists of 'sequencing, parallelism, and priority.' Such relationship was not explicitly represented with a sequential visualization (Figure VII a). This observation suggests making these relationships more visually explicit as a complementary way of interpreting the matrices. He also emphasized the importance of clarifying the meaning of a 'priority' relationship, as he did not consider it to be as numerically intuitive as the other variables (Figure VII b).

*Figure VII – sequencing and parallelism and priority in process flowcharts.*
*Source: authors, 'a' based in Bostock (2023), 'b' based in Abrate (2022).*

According to Role 4, the matrix maps were useful and, based on their professional experience, suggested creating two additional visualizations related to an organizational structure map and process flowcharts. The use of flowcharts in the plural was clarified; Role 4 believes it is important to print the flowchart of a subprocess separately from the overall operation. This way, the visualization would be more readable and useful for other purposes, such as instructing a role in their activities. Roles 1, 3, and 6 also emphasized the importance of a clear, simple, linear, temporally ordered flowchart visualization that uses colors to differentiate flows and updates with data insertions and adjustments (Figure VII b).

Figure VII exhibits two visualizations that represent the [a] linear sequence and [b] stair-step sequence of nursing activities. 'a' was introduced to the users, and 'b' is the alternative visualization developed in response to the need for improving the understanding of priority data. Unlike the linear sequence, which merely indicates precedence relationships, the 'stair-step' representation conveys the time required to execute a task by graphically combining information on precedence, parallelism, and propriety that has been processed.

In complex work organization designs, the stair-step activities sequence serves as a starting point for organizing space allocation and mobilizing human resources based on activities. For instance, the overlap of four activities at stair-step 5 (Figure VII b) indicates four parallel activities, which, when carried out by a single agent, will extend the duration. This time extension can adversely affect activities that rely on these, as indicated by downstream connections in subsequent steps. Furthermore, the sequence of stair-step activities can also be compared with the activity and environment matrices (Figure VI), enabling to identify groups of dependent activities that should be allocated together to enhance congruence. For instance, in the specific case regarding the four activities in step 5 (Figure VII b), it is observed that one of them serves as a common dependency for activities that take place three-time intervals later. Step 8 presents a set of six concurrent and parallel activities, with four of them dependent on this common precedence. This occurrence suggests a physical arrangement that facilitates the flow between the spaces where the activities will be allocated. It also suggests that the precedence activity has lower priority than the others indicated in step 5 since they precede activities that take place in subsequent time intervals.

Another type of visualization requested by Roles 2, 6, and 7 is visualizing the flow within the environment. In other words, indicating the path of activities on the architectural floor plan where they are allocated. For Role 6, this visualization would be useful to define and document alternative flows for support activities such as waste collection, cleaning, and delivery of cleaning materials, in the event of temporary closure due to maintenance, isolation needs, etc. Spatial mapping can be done in both an existing

environment to record the organization's reality and in a designed environment to anticipate how flows will fit into the designed environment (Figure VIII).

*Figure VIII – space allocation in floor plan, best-first path*
*Source: authors*

Processing and visualization programming is no minor problem. The developed visualization geometrically models the floor plan using database information; performs the best-first search of the path; and represents these paths on the plan one by one. To test the impact of a closed corridor, for instance, the user must impose a passage restriction and reprocess the paths. Currently, a dynamic approach is under development to represent these interferences and enhance the graphical quality of the indicated pathways.

## 5 CONCLUSION

The MAEA was tested by individuals in managerial roles at HUUSP. The organization was used as a case study to gather information regarding the functioning of a department, the hospital's emergency room, and to provide data for developing the method and software. Test participants interacted with the MAEA, operating its key functions, and had the opportunity to analyze and evaluate the results. The participants' feedback and impressions were collected as evidence through interviews and during the test, with concurrent think-aloud recording. This material was employed to inform evidence-based design improvements.

The MAEA was successfully utilized by all participants, including those with limited computer literacy. This suggests a broader usability range without the need for specialized AECO knowledge. This feature is crucial for its widespread use by managers and personnel within the organization, particularly in cases with decentralized data collection strategies. For such applications, another notable aspect of the software is that it is easy to use in terms of data import and export systems. Overall, all commands and data input management windows were well-received.

One improvement aspect that raised concerns is how the mapping results are visualized. Participants expressed a desire for greater dynamism and different visualization perspectives. The visualization preferences voiced in the interviews aligned with InfoVis propositions developed according to guidelines from workshops with designers: the focus on multiple, readable perspectives forming a more complex and transparent scenario of overall information aligns with that discussed in Pereira, Ornstein and Velloso (2023). As anticipated in this study, it was observed that interpreting the results requires engagement and time to analyze the multiple dimensions (or domains) of the mapping.

In addition to DSM and MDM, participants were introduced to and could interpret InfoVis representations of flowcharts indicating priority and parallelism, as well as the flow of activities within the

defined floor plan. These visualizations were generated by the researcher based on the data updated by the participants. This occurred because additional visualization functions were not implemented in the tested software. The InfoVis was generated externally (using an online Python resource) and presented to participants as a future implementation possibility to be confirmed if they met their demands. Users acknowledged that the presented multidomain mapping strategy was appropriate. They expressed a clear understanding of the method's specific applications in their activities, as well as the organizational implications for an application focused on potential overall gains. It is a management support tool that requires little operating knowledge but, on the other hand, demands quality content input. This requirement is directly linked to the commitment, professional knowledge, and practical experience of the software users regarding the mapped activities, which are fed into the database. It is also influenced by the time available to work with the data and collaborate with other roles. The latter conditions depend on promoting mapping, which is endorsed by the organization's top-level management.

A team or role responsible for the project is tasked with auditing the data to ensure balance and consistency. The software highlights where inconsistencies occur, helping with this task. Potential mapping gains were identified even before allocation to an existing or designed special arrangement. The stair-step diagram and process matrix help to identify activities that should be located close to one another in the environment to reduce delays and facilitate interaction between roles.

The MAEA provides an effective method for mapping relationships between spatial layouts and activities into a work organization. Its adoption proved to be valuable in analyzing existing and proposed spaces allocations. Furthermore, it serves as a versatile tool within multimethod assessments, complementing qualitative and quantitative approaches, including Post-Occupancy Evaluations (POEs), actor–network investigations, individual interviews, focus groups, space syntax analysis, questionnaire surveys, etc. (Gharipour *et al.*, 2023; Salaheldin *et al.*, 2021; Sharif, 2023). In summary, the discuss indicates that the method significantly contributes to design enhancement by identifying allocation patterns, establishing design criteria, and laying the groundwork for the development of initial, effective, and accessible metrics for architectural design evaluations. These contributions are particularly valuable for assisting in the negotiation and mediation of decisions in participatory design processes related to activity allocation, providing evidence of performance for organizational work structuring.

**Enhancements implemented and under development:** The software adjustments resulting from error diagnosis, and improvements obtained through testing were carried out. The ensuing beta version will be utilized in the first use case in a real design process (in another research). It is available at the following links [https://github.com/LC-MP/MAEA] or [http://repositorio.uspdigital.usp.br/handle/item/570] and [http://repositorio.uspdigital.usp.br/handle/item/572]. This version includes all management commands,

database visualization features, and some of the developed visualization results. The remaining implementations will be available in the next version at the same link, to be used in the analysis of a real project, which is currently in its early stages in the aforementioned use case. The procedure manual is under development and will be made available, along with the software, by the end of the research.

**Future studies**: The focus on the relationship between the organization's environment and its processes does not consider variables such as the availability of resources necessary to execute the activity; this additional domain will be a valuable addition to the current mapping. Although the software provides fields for recording work shifts, the method offers a timeless planning mapping; introducing time and other discrete variables will be an important addition to be used by operations management. We suggest research aimed at exploring innovative approaches to visualize the data set in its multiple domains and specific views, which will allow more elaborate insights from project and design teams. The current software is a standalone application; experimental development conditions prevented a web-based service approach. Developing this approach will enable to explore the computational potential for data sharing and indexing, which is important for AI and big data-based solutions. The possibility of mapping multiple cases and making the data available for meta-analyses offers a promising field for new discoveries, as it allows the development of statistical approaches to aggregate responses. Finally, we extend an invitation to fellow researchers and AECO professionals to employ the proposed method in their work and disseminate their findings. This collaborative effort will not only facilitate a comprehensive evaluation of the method but also contribute to refining its suitability and enhancing its practical utility within the field. It is also possible to integrate the method with CAD/BIM software, which would streamline the capture of topological data from spaces. Such an approach represents another avenue for development.

**Acknowledgments**: This work was supported by the São Paulo State Research Foundation – FAPESP [grant numbers 2020/15909-8]; and the National Council for Scientific and Technological Development – CNPq [grant number 304131/2020-2]. We are grateful to the University Hospital of the University of São Paulo for allowing the research and the professionals for agreeing to cooperate with the test and interview process. We are also grateful to Jean Amaro, Vitória Sanches Lemes Soares, Edson Prado Bomfim, and Daniela Cariolin Mazzi, Professor Leandro M. Reis Velloso and FAUUSP students for their data collection collaboration, and for developing and implementing program improvements.

**Conflicts of Interest**: The authors declare no conflict of interest.

## References

Abrate, M. (2022), “Tangled tree visualization”, *Observable*, licence type: MIT, available at: https://observablehq.com/@nitaku/tangled-tree-visualization-ii.

Akintola, Y., Senthilkumar, V. and Root, D.S. (2015), “Identification of process, team and tool dependencies in building information modelling (BIM) implementation using multi-domain

mapping (MDM) - A theoretical framework", *Modeling and Managing Complex Systems - Proceedings of the 17th International DSM Conference*, Carl Hanser Verlag GmbH & Co. KG, pp. 65–74, doi: 10.3139/9783446447264.007.

Balagtas-Fernandez, F. and Hussmann, H. (2009), "A methodology and framework to simplify usability analysis of mobile applications", *ASE2009 - 24th IEEE/ACM International Conference on Automated Software Engineering*, IEEE, pp. 520–524, doi: 10.1109/ASE.2009.12.

Baldry, C. (1999), "Space - The final frontier", *Sociology*, Vol. 33 No. 3, pp. 535–553, doi: 10.1177/s0038038599000346.

Bolton, R., Logan, C. and Gittell, J.H. (2021), "Revisiting Relational Coordination: A Systematic Review", *The Journal of Applied Behavioral Science*, Vol. 57 No. 3, pp. 290–322, doi: 10.1177/0021886321991597.

Bostock, M. (2023), "Arc diagram", *Observable*, licence type: ISC, available at: https://observablehq.com/@d3/arc-diagram.

Browning, T.R. (2016), "Design Structure Matrix Extensions and Innovations: A Survey and New Opportunities", *IEEE Transactions on Engineering Management*, IEEE, Vol. 63 No. 1, pp. 27–52, doi: 10.1109/TEM.2015.2491283.

Calixto, V. and Celani, G. (2015), "A literature review for space planning optimization using an evolutionary algorithm approach: 1992-2014", *Anais Do XIX Congresso Da Sociedade Ibero-Americana de Gráfica Digital 2015*, Vol. 2, Editora Edgard Blücher, São Paulo, pp. 662–671, doi: 10.5151/despro-sigradi2015-110166.

Cao, X., Li, X., Yan, Y. and Yuan, X. (2018), "Skeleton and infill housing construction delivery process optimization based on the design structure matrix", *Sustainability (Switzerland)*, Vol. 10 No. 12, doi: 10.3390/su10124570.

Diah, N.M., Ismail, M., Ahmad, S. and Dahari, M.K.M. (2010), "Usability testing for educational computer game using observation method", *Proceedings - 2010 International Conference on Information Retrieval and Knowledge Management: Exploring the Invisible World, CAMP'10*, IEEE, pp. 157–161, doi: 10.1109/INFRKM.2010.5466926.

Dorrah, D.H. and Marzouk, M. (2021), "Integrated multi-objective optimization and agent-based building occupancy modeling for space layout planning", *Journal of Building Engineering*, Elsevier Ltd, Vol. 34 No. January 2020, p. 101902, doi: 10.1016/j.jobe.2020.101902.

Eppinger, S.D. and Browning, T.R. (2012), *Design Structure Matrix Methods and Applications*, edited by Moses, J., Neufville, R. de, Heitor, M., Morgan, G., Pate-Cornel, E. and Rouse, W., 1st ed., The MIT Press, Cambridge, doi: 10.7551/mitpress/8896.001.0001.

Ezzeldin, M., Assem, A. and Abdelmohsen, S. (2021), "Automated assessment of architectural spatial layout configurations using fuzzy logic", *Archnet-IJAR: International Journal of Architectural Research*, Vol. 15 No. 2, pp. 328–343, doi: 10.1108/ARCH-07-2020-0135.

Fan, M., Lin, J., Chung, C. and Truong, K.N. (2019), "Concurrent think-aloud verbalizations and usability problems", *ACM Transactions on Computer-Human Interaction*, Vol. 26 No. 5, doi: 10.1145/3325281.

Ferri, M., Zygun, D.A., Harrison, A. and Stelfox, H.T. (2015), "Evidence-based design in an intensive care unit: End-user perceptions", *BMC Anesthesiology*, Vol. 15 No. 1, p. 57, doi: 10.1186/s12871-015-0038-4.

Gharipour, M., Tyne, I.A., Afsary, S., Hemme, N. and Trout, A.L. (2023), "A community healthcare clinic in Baltimore: healing environment, design criteria, and assessment metrics", *Archnet-IJAR: International Journal of Architectural Research*, Emerald Publishing Limited, Vol. 17 No. 4, pp. 609–627, doi: 10.1108/ARCH-02-2022-0051.

Goodman, E., Mike, K. and Moed, A. (2003), *Observing the User Experience: A Practitioner's Guide to User Research*, *Observing the User Experience*, 2nd ed., Elsevier, doi: 10.1016/B978-1-55860-923-5.X5026-8.

Hickethier, G., Tommelein, I.D., Hofmann, M., Lostuvali, B. and Gehbauer, F. (2011), "MDM as a tool to improve BIM development processes", *Invest on Visualization - Proceedings of the 13th*

*International DSM Conference*, pp. 349–362.

Lee, J., Deng, W.Y., Lee, W.T., Lee, S.J., Hsu, K.H. and Ma, S.P. (2010), "Integrating process and work breakdown structure with design structure matrix", *Journal of Advanced Computational Intelligence and Intelligent Informatics*, Vol. 14 No. 5, pp. 512–522, doi: 10.20965/jaciii.2010.p0512.

Leone, L. (2023), "Is There Still a Place for Space in Organization Studies?", *Journal of Management Inquiry*, Vol. 32 No. 4, pp. 338–342, doi: 10.1177/10564926231179324.

Liggett, R.S. and Mitchell, W.J. (1981), "Optimal space planning in practice", *Computer-Aided Design*, Vol. 13 No. 5, pp. 277–288, doi: 10.1016/0010-4485(81)90317-1.

Morgareidge, D., CAI, H. and JIA, J. (2014), "Performance-driven design with the support of digital tools: Applying discrete event simulation and space syntax on the design of the emergency department", *Frontiers of Architectural Research*, Elsevier, Vol. 3 No. 3, pp. 250–264, doi: 10.1016/j.foar.2014.04.006.

Pektaş, Ş.T. and Pultar, M. (2006), "Modelling detailed information flows in building design with the parameter-based design structure matrix", *Design Studies*, Vol. 27 No. 1, pp. 99–122, doi: 10.1016/j.destud.2005.07.004.

Pereira, L.M. (2019), *A Influência Organizacional Sobre a Qualidade Do Projeto Do Ambiente Construído*, Universidade de São Paulo. São Carlos, São Carlos, 26 November, doi: 10.11606/T.102.2019.tde-25112019-101345.

Pereira, L.M. and Amaro, J. (2023), "Multidomain Congruence Mapping (MCM): developed for postdoctoral research", github, São Paulo.

Pereira, L.M. and Ornstein, S.W. (2023a), "A Systematic Literature Review on Healthcare Facility Evaluation Methods", *HERD: Health Environments Research & Design Journal*, Vol. 16 No. 3, pp. 338–361, doi: 10.1177/19375867231166094.

Pereira, L.M. and Ornstein, S.W. (2023b), "Avaliação da alocação das atividades aplicada a um pronto-socorro hospitalar adulto: uma análise comparada com os achados de Avaliação Pós-Ocupação", *Revista Instituto de Pesquisas Hospitalares (IPH)*.

Pereira, L.M., Ornstein, S.W., Soares, V.S.L., Amaro, J. and França, A.J.G.L. (2023), "Congruence Mapping of the Activity Flows Allocated in Built Environments: A Pilot Application of Under-Development Software in an Emergency-Care Service", *Applied Sciences*, Vol. 13 No. 3, p. 1599, doi: 10.3390/app13031599.

Pereira, L.M., Ornstein, S.W. and Velloso, L.M.R. (2023), "Analysis of InfoVis Proposals for a Built Environment Activity Allocation Software", *Simpósio Brasileiro de Qualidade de Projeto No Ambiente Construído - SBQP*, PROGRAU/UFPEL, Pelotas, pp. xx-yy.

Rahbar, M., Mahdavinejad, M., Bemanian, M., Davaie Markazi, A.H. and Hovestadt, L. (2019), "Generating Synthetic Space Allocation Probability Layouts Based on Trained Conditional-GANs", *Applied Artificial Intelligence*, Taylor & Francis, Vol. 33 No. 8, pp. 689–705, doi: 10.1080/08839514.2019.1592919.

Reichardt, T., Elezi, F., Tommelein, I.D. and Lindemann, U. (2012), "Creating dynamic organizational modularity in lean construction design – combining MDM and DSM methodology systematically", *Gain Competitive Advantage by Managing Complexity*, Carl Hanser Verlag GmbH & Co. KG, München, pp. 343–355, doi: 10.3139/9783446434127.027.

Saha, N., Haymaker, J. and Shelden, D. (2020), "Space allocation techniques (SAT). Computable design problems and integrated framework of solvers", *Proceedings of the 40th Annual Conference of the Association for Computer Aided Design in Architecture: Distributed Proximities, ACADIA 2020*, Vol. 1, pp. 248–257.

Salaheldin, M.H., Hassanain, M.A. and Ibrahim, A.M. (2021), "A systematic conduct of POE for polyclinic facilities in Saudi Arabia", *Archnet-IJAR: International Journal of Architectural Research*, Emerald Publishing Limited, Vol. 15 No. 2, pp. 344–363, doi: 10.1108/ARCH-08-2020-0156.

Salama, A.M. (2019), "Methodological research in architecture and allied disciplines: Philosophical positions, frames of reference, and spheres of inquiry", *Archnet-IJAR*, Vol. 13 No. 1, pp. 8–24, doi:

10.1108/ARCH-01-2019-0012.
Sanchez, R. and Mahoney, J.T. (1996), "Modularity, flexibility, and knowledge management in product and organization design", *Strategic Management Journal*, John Wiley & Sons, Ltd, Vol. 17 No. S2, pp. 63–76, doi: 10.1002/smj.4250171107.
Schmidt, R., Vibaek, K.S. and Austin, S. (2014), "Evaluating the adaptability of an industrialized building using dependency structure matrices", *Construction Management and Economics*, Vol. 32 No. 1–2, pp. 160–182, doi: 10.1080/01446193.2013.847274.
Senthilkumar, V. and Varghese, K. (2009), "Structured methodology to formulate drawing dependency structure matrix for construction design", *Architectural Engineering and Design Management*, Vol. 5 No. 4, pp. 225–248, doi: 10.3763/aedm.2008.0103.
Sharif, A.A. (2023), "Towards a relational approach for understanding the multiplicity of sitting activities", *Archnet-IJAR: International Journal of Architectural Research*, Emerald Publishing Limited, Vol. 17 No. 4, pp. 686–702, doi: 10.1108/ARCH-01-2022-0002.
Shin, S., Jeong, S., Lee, J., Hong, S.W. and Jung, S. (2017), "Pre-Occupancy Evaluation based on user behavior prediction in 3D virtual simulation", *Automation in Construction*, Elsevier B.V., Vol. 74, pp. 55–65, doi: 10.1016/j.autcon.2016.11.005.
Sinha, K., James, D., Weck, O. De and Weck, O. De. (2012), "Interplay between product architecture and organizational structure", *Gain Competitive Advantage by Managing Complexity - Proceedings of the 14th International DSM Conference, DSM 2012*, pp. 275–288.
Soares, V.S.L., Ornstein, S.W. and França, A.J.G.L. (2024), "Evaluation of an emergency room in operation during the COVID-19 pandemic: diagnoses and recommendations concerning environmental factors", *Frontiers in Built Environment*, Vol. 9 No. January, pp. 1–20, doi: 10.3389/fbuil.2023.1331970.
Sosa, M.E. (2007), "Aligning process, product, and organizational architectures in software development", *Proceedings of ICED 2007, the 16th International Conference on Engineering Design*, Vol. DS 42, pp. 1–12.
Sosa, M.E., Eppinger, S.D. and Rowles, C.M. (2000), "Designing Modular and Integrative Systems", *DETC2000 / ASME 2000: International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, Vol. DTM-14571, ASME, pp. 1–10.
Unger, D. and Eppinger, S. (2011), "Improving product development process design: A method for managing information flows, risks, and iterations", *Journal of Engineering Design*, Vol. 22 No. 10, pp. 689–699, doi: 10.1080/09544828.2010.524886.
Vanbrabant, L., Braekers, K., Ramaekers, K. and Van Nieuwenhuyse, I. (2019), "Simulation of emergency department operations: A comprehensive review of KPIs and operational improvements", *Computers and Industrial Engineering*, Elsevier, Vol. 131 No. March, pp. 356–381, doi: 10.1016/j.cie.2019.03.025.
Vanbrabant, L., Martin, N., Ramaekers, K. and Braekers, K. (2019), "Quality of input data in emergency department simulations: Framework and assessment techniques", *Simulation Modelling Practice and Theory*, Elsevier, Vol. 91 No. September 2018, pp. 83–101, doi: 10.1016/j.simpat.2018.12.002.
Voordijk, H., Meijboom, B. and de Haan, J. (2006), "Modularity in supply chains: a multiple case study in the construction industry", *International Journal of Operations & Production Management*, Emerald Group Publishing Limited, Vol. 26 No. 6, pp. 600–618, doi: 10.1108/01443570610666966.
Wilschut, T., Etman, L.F.P., Rooda, J.E. and Vogel, J.A. (2018), "Generation of a function-component-parameter multi-domain matrix from structured textual function specifications", *Research in Engineering Design*, Springer London, Vol. 29 No. 4, pp. 531–546, doi: 10.1007/s00163-018-0284-9.
Zhang, D. and Adipat, B. (2005), "Challenges, methodologies, and issues in the usability testing of mobile applications", *International Journal of Human-Computer Interaction*, Vol. 18 No. 3, pp. 293–308, doi: 10.1207/s15327590ijhc1803_3.
Zhao, T., McDonald, S. and Edwards, H.M. (2014), "The impact of two different think-aloud instructions in a usability test: A case of just following orders?", *Behaviour and Information Technology*, Vol.

33 No. 2, pp. 163–183, doi: 10.1080/0144929X.2012.708786.

*Table I – Duration of Tests and Interviews.*

| ID – sector; | gender; | formation | Date | Test | Interview | Total |
|---|---|---|---|---|---|---|
| Role 1 – Nutrition | fem. | graduate | Aug.23, 2023 | 48 min | 07 min | 55 min |
| Role 2 – Facility | mas. | graduate | Aug.24, 2023 | 30 min | 06 min | 36 min |
| Role 3 – Nursing | fem. | graduate | Aug.24, 2023 | 21 min | 10 min | 31 min |
| Role 4 – Medicine | fem. | graduate | Aug.28, 2023 | 26 min | 05 min | 31 min |
| Role 5 – Cleaning Serv. | fem. | technical | Aug.28, 2023 | 29 min | 16 min | 45 min |
| Role 6 – Linen Service | fem. | technical | Aug.28, 2023 | 30 min | 10 min | 40 min |
| Role 7 – Pharmacy | mas. | graduate | Aug.29, 2023 | 55 min | 11 min | 66 min |

*Source: authors*

*Table II - Usability Test Script.*

| **Test script. These steps should be followed to execute the test:** |
|---|
| 1. Open the program and see how it is organized. |
| 2. Check the activities that have already been entered into the system based on the interviews conducted. |
| 3. Edit activities with any incorrectly provided information. |
| 4. Add missing activities, considering the following information: |
| a. Name the activity. |
| b. Specify the function responsible for the activity. |
| c. Indicate the relationships between the added activity and other activities. |
| d. Identify the locations within the facility where the added activity takes place. |
| 5. Test the export and import data features from a CSV file (open in Excel). |
| 6. Test the commands to view results: |
| a. Relationships between activities matrix. |
| b. Relationships between spaces matrix. |
| c. Relationships between spaces and activities matrix. |
| d. Congruence of activities matrix. |
| e. Congruence of spaces matrix. |
| **Execute Test. The researcher should execute the test as follows:** |
| **1. At the beginning of the test:** |
| a. Start recording. |
| b. Request the Participant's Informed Consent form (PIC) signature or inform them that it has already been signed previously. |
| c. Explain the purpose of the test, so invite the participant to start it and, to concurrent thinking aloud (like brainstorming). |
| 2. During the test: |
| a. The researcher presents the program as the participant performs the guided test. |
| b. The researcher should support the participant in the following ways: |
| - Answering questions as requested by the participant. |
| - Drawing attention to details not noticed by the participant before. |
| - Exceptionally, the researcher may demonstrate how to perform a specific operation to illustrate what was verbally explained. |
| 3. Log records: |
| a. The researcher should note key points they identify as they observe how to use the test |

*Source: authors*

*Table III - Semi-Structured Interview Script: Instrument Diagnosis.*

| **The interview consists of five questions:** |
|---|
| 1. Did you manipulate existing data or operate the instrument provided? If so, please describe your experience. Identify any difficulties or suggest changes to enhance the operational experience. |
| 2. Were the mapping representation formats clarifying? Do you recommend adjustments, improvements, or alternative representation formats? |
| 3. Do you believe there are any issues concerning the functionality of the Pre-Design Evaluation Instrument (PDE)? If so, please specify. |
| 4. Do the results obtained with the Pre-Design Evaluation (PDE) provide adequate information to support the evaluation of the current situation in the emergency department? |
| 5. Would you like to add any further comments? |

*Source: authors*

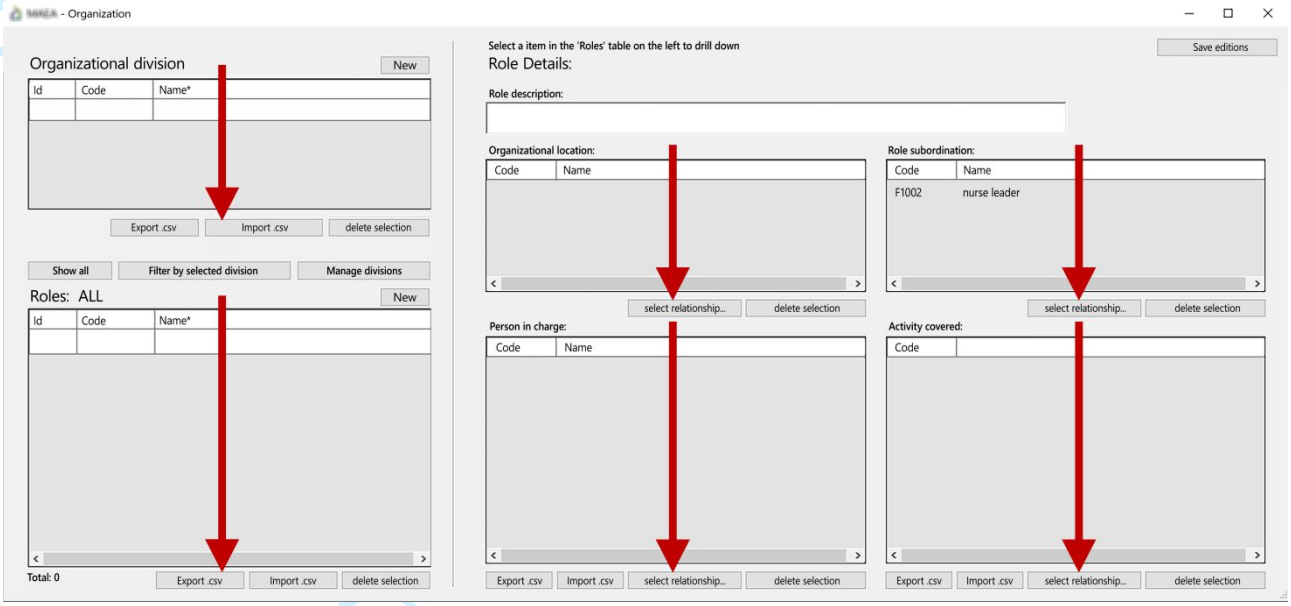
*Table IV - Summary of Interview Responses after Testing.*

| **Did you manipulate existing data and operate the Pre-Design Evaluated instrument (PDE) made available? If yes, describe the experience:** | | | | | |
|---|---|---|---|---|---|
| **Questions:** / **Roles** | 1. Identify any difficulties or improvement suggestions to enhance the operational experience. | 2. Were the forms of representation clarifying? Recommend improvements, adjustments, or alternative representation. | 3. Did you identify any issues with the use of the APP instrument? If yes, please specify. | 4. Do the obtained results provide adequate information to support the evaluation of the existing situation? | 5. Would you like to add any further comments? |
| **Role 1. Nutrition** | Proposed implementing a structure that allows indicating 'macro activities' before and after detailing these activities if necessary, breaking them down into specific activities. A process > subprocess > macro activity > activity logic. | Recommended developing flowchart visualization methods, suggesting a clearer indication of flows. | - Believes it is important to develop a user instruction manual.<br>- Observed that it was challenging to insert an activity into an existing sequence of activities. | Yes. Emphasized that, in addition to the intended use, believes the results are useful for educational purposes in teaching professional practice, especially in a university hospital and particularly within their department. | Did not provide additional comments. |
| **Role 2. Facility** | Suggested that it would be better to double-click on a group to filter the items grouped within it. | Suggested using color systems to differentiate flow visualization. | Had trouble orienting the sequence of the item list. | Yes. Particularly in a renovation, it is necessary to segment and isolate a space without disrupting the functioning of healthcare activities. | Did not provide additional comments. |
| **Role 3. Nursing** | Considering it was her first time using it, the interviewee found it to be good. Initially, she thought the interface was somewhat cluttered but well-organized; once she understood the structure, it was easy to use. | Recommended representations that provide a spatial sense, like floor plans. | Did not identify any problems. | Yes. Believes that the results offer the possibility to assess and guide the activities of each function to other functions. Considers it important to 'align' the process and the environment. | Believes it is important to integrate the emergency room environment and process to ensure that the proposed arrangement meets the demands and does not repeat issues from the existing spatial arrangement. |
| **Role 4. Medicine** | Felt that she would not be able to perform operations without the support of the researcher who accompanied the test. She could not say whether a manual or instructional video would be sufficient resources, as she does not typically use a PC. | Understood the relationships presented for the process and environment, including sequencing, parallelism, and priority. Felt it was important to clarify the meaning of the latter. | Did not identify any problems. | Found the results illuminating for understanding the service's operational dynamics. | Pointed out concern about adjusting the content to include adequate detailing and achieving coherence among records from different functions. |
| **Role 5. Cleaning Service** | Found it easy to handle and was able to 'connect' functions and processes. Emphasized the importance of considering the timing and periodicity of activities and the ability to insert subprocesses within processes. | Identified a visualization issue due to the volume of information involved. Suggested studying ways to simplify and guide visualizations, such as highlighting the links within a subprocess, function, or activity. Emphasized the need to highlight 'critical points.' | Did not identify any problems or difficulties to use it. | Found the presented mappings useful and suggested the development of:<br>- Organizational map,<br>- dynamic flowcharts. | Noted that having time to use the program and input all the work data would be important to provide a more informed and detailed constructive critique of its use. |
| **Role 6. Linen Service** | Found it easy to use with the researcher's guidance. Felt the need for a tutorial that clarifies the logic of how the ensemble > entity > relation works. Practice might overcome any potential difficulty. | Found matrix graphs challenging to grasp. Understanding them is not intuitive and requires explanation and training. | Did not identify any problems or difficulties to use it. | Did not clearly understand how to visualize the results. Highlighted the usefulness of the relationships and the importance of mapping flows as it provides support for defining alternative collection flows (flowchart). | Found the program is important; it is a path that the organization needs to embrace to effectively use it for operational improvements and management. |
| **Role 7. Pharmacy** | Highlighted the good linear reasoning of the process as a positive aspect and the lack of double-click functionality for commands other than editing as a negative point. | Found matrices difficult to understand. | Observed data relationship shuffling. | Provides the process mapping with Spaces. | Mentioned that mapping allows improving the performance of employees, justifying personnel hiring, redirecting investments, and reducing waste. |

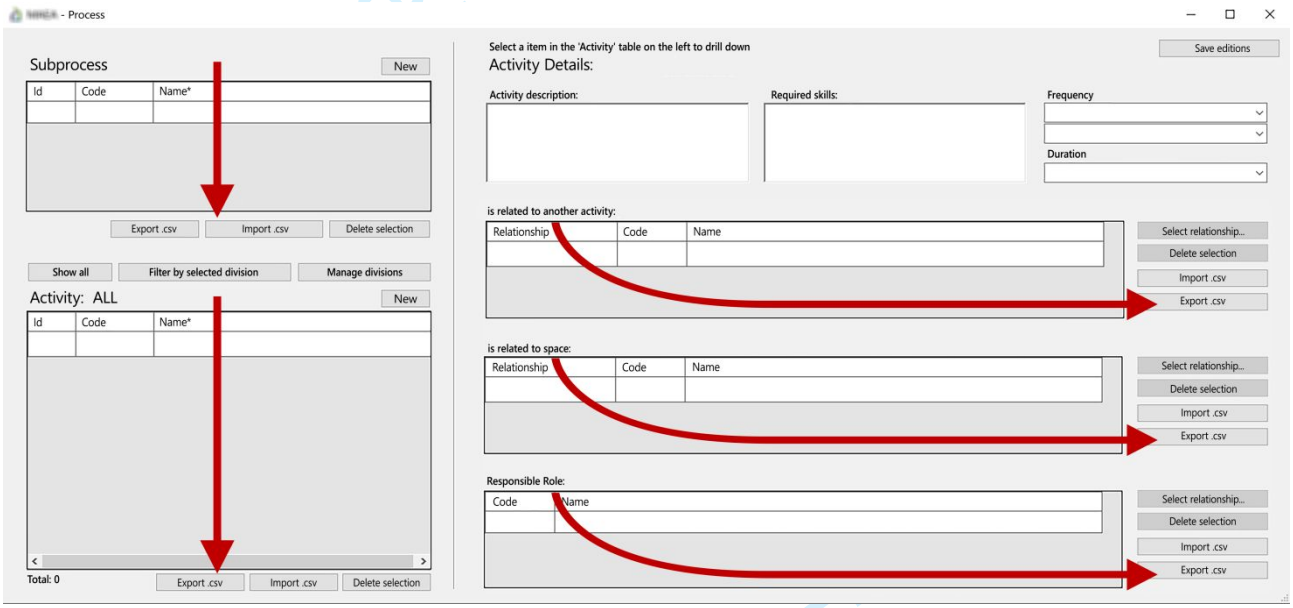
*Fonts: authors*

*Figure I – default layout [a] with vertical reading, and alternative layout [b] with mixed vertical and horizontal reading*

[a]

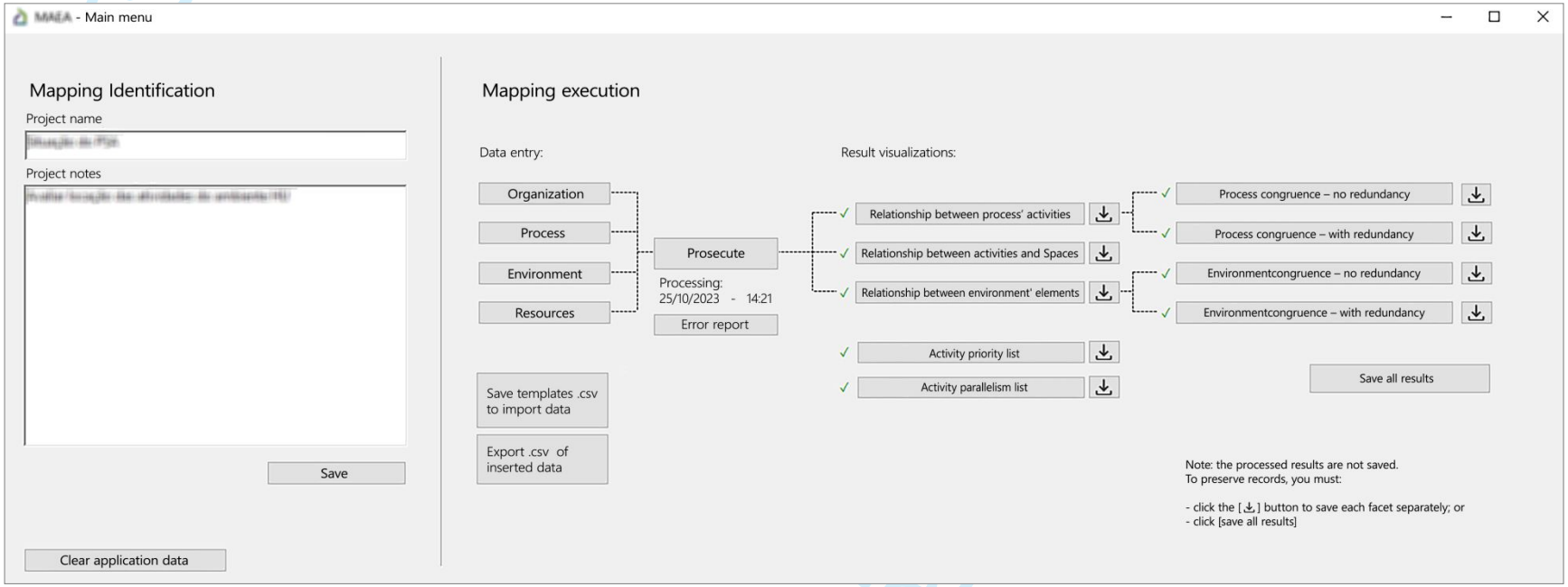



[b]



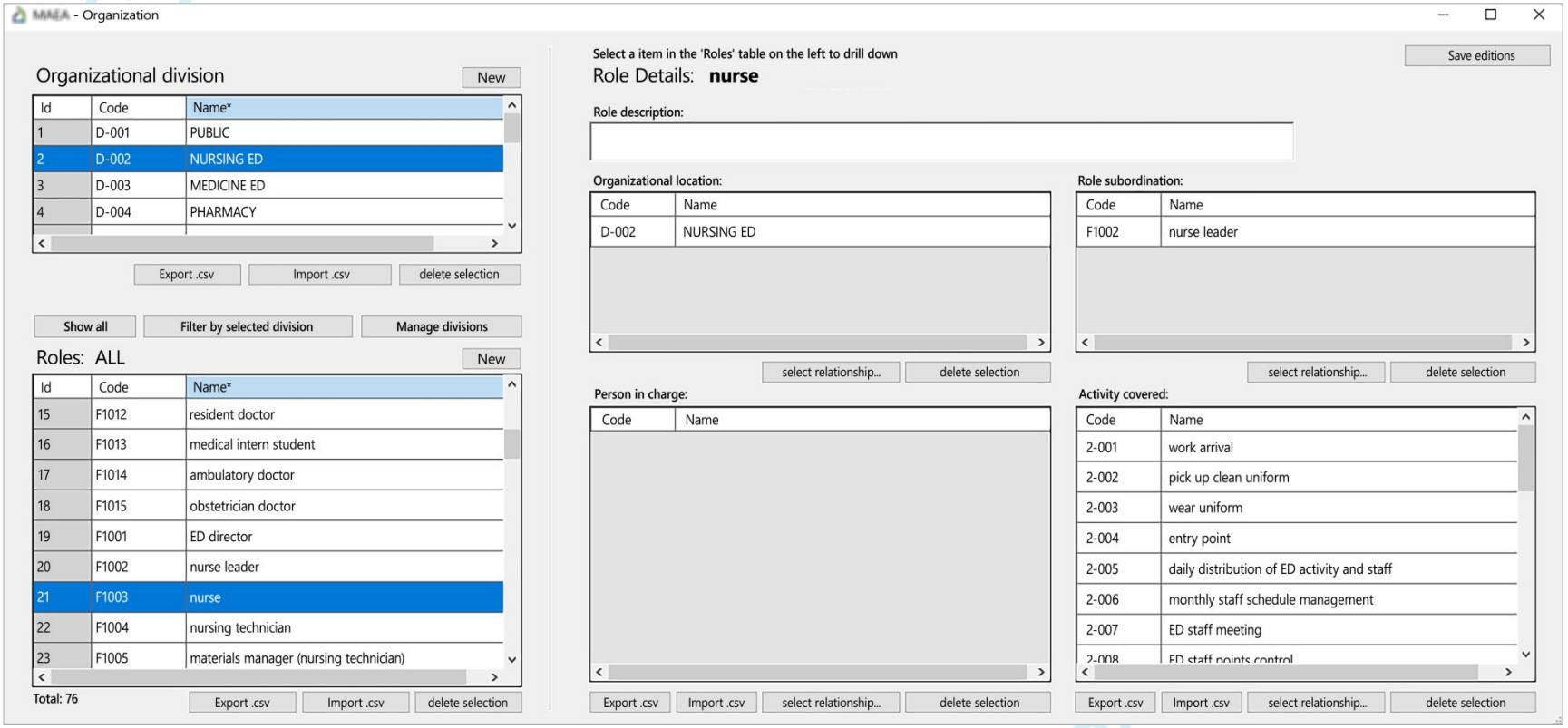

*Source: authors*

*Figure II – home page*



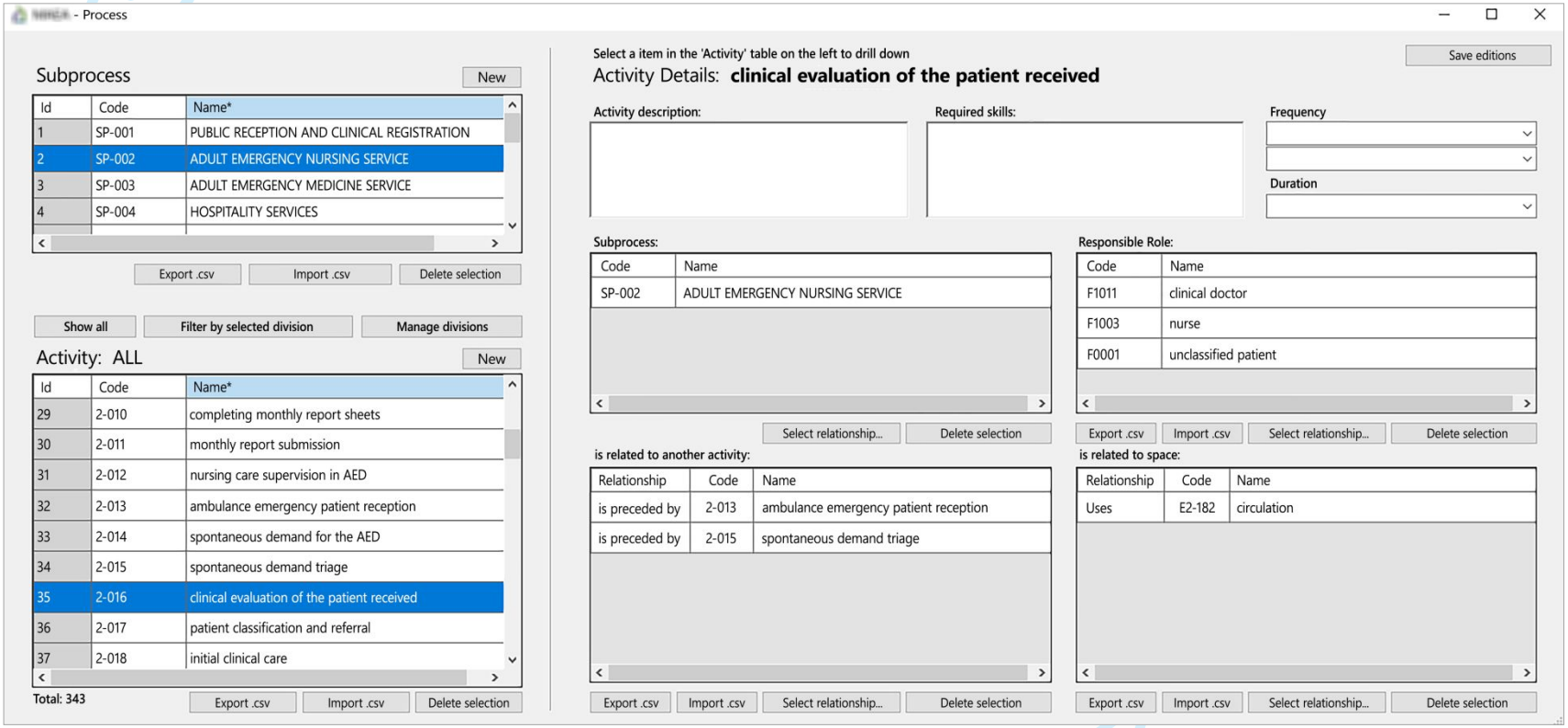

*Source: authors.*

*Figure III – data management page example: organization page*



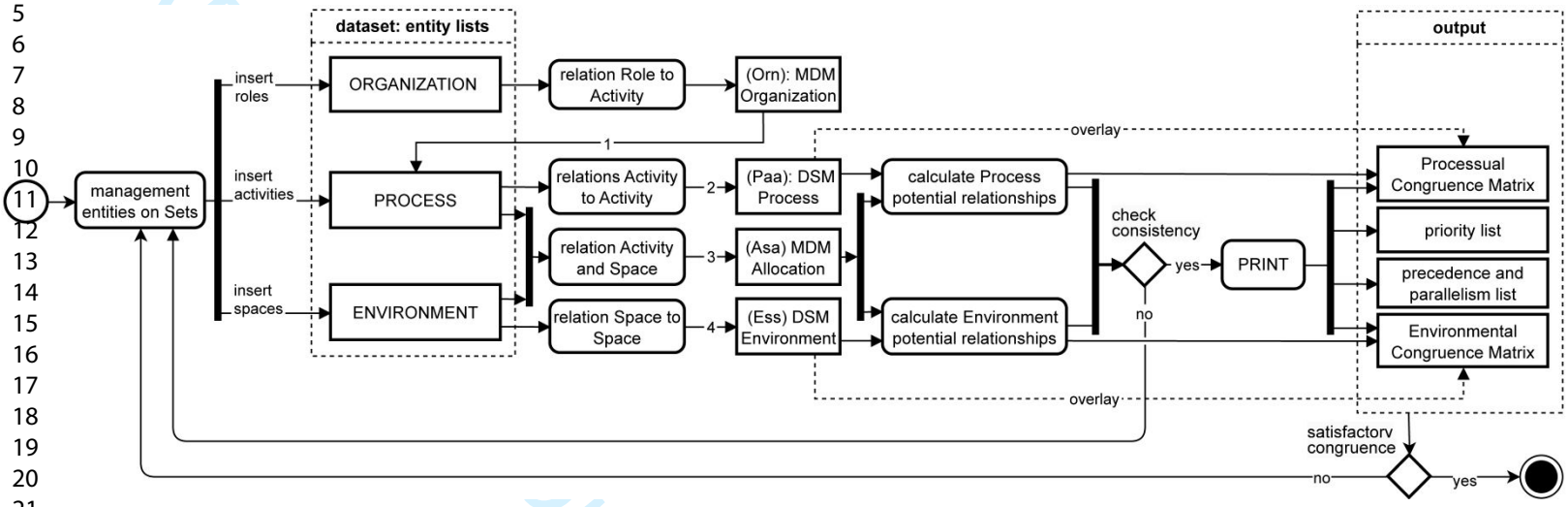

*Source: authors*

*Figure IV – process page*




*Source: authors.*

*Figure V – usage procedure scheme*




*Note / Legend:*
*The relationships between 'Sets' and 'Entity' are many-to-many (N-N), ensuring flexibility in grouping based on the type of existing organizations.*

1 - *defines relationships between Roles and Activities of a work organization - the organization assigns roles to activities; activities are actions within a process with defined and expected outcomes;*

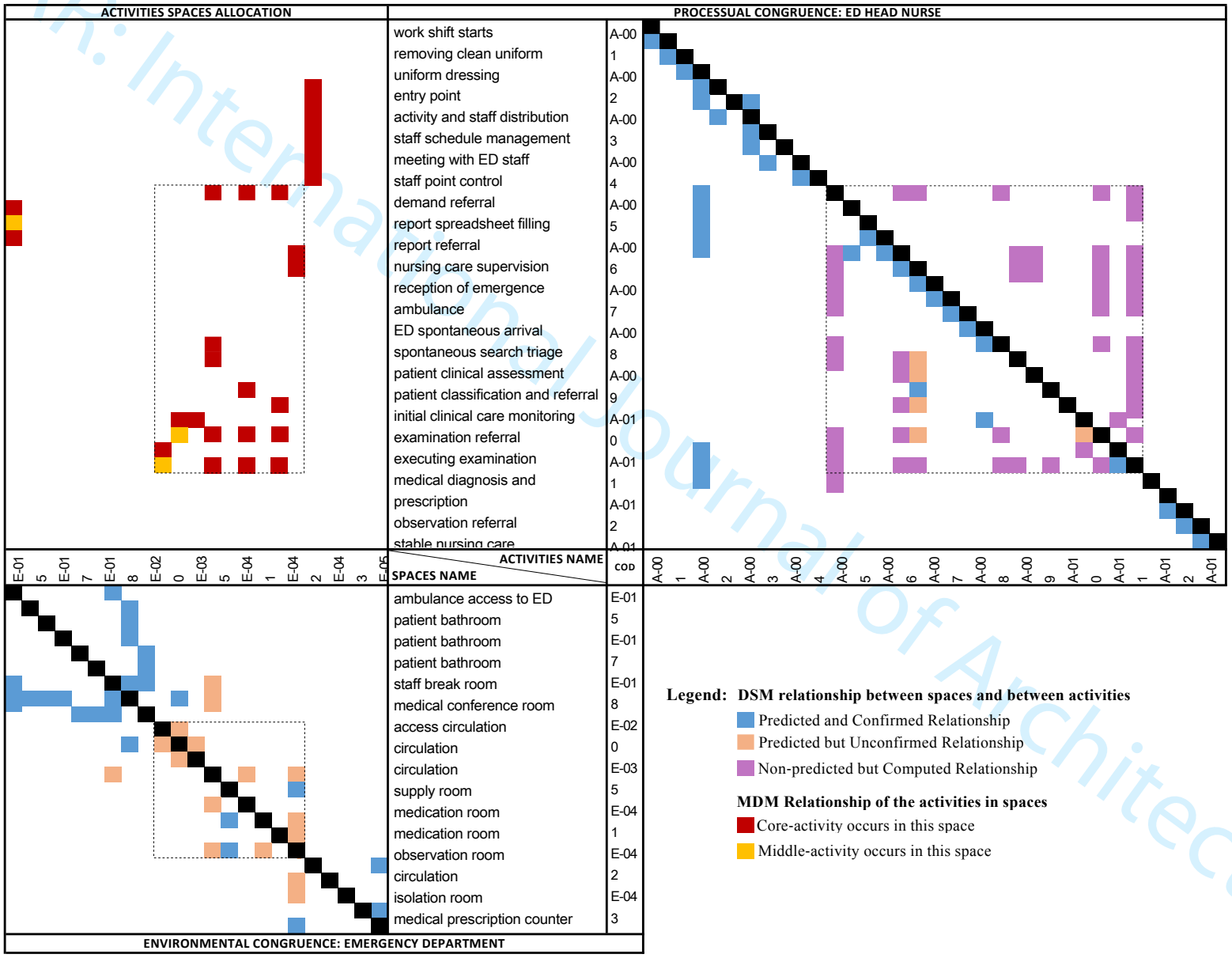
2 - *defines relationships between Activities of a process;*

3 - *defines relationships between Spaces and Activities - all actions associated with roles to carry out these activities are performed within one or more spaces,*

4 - *defines relationships between Spaces of building - these spaces constitute parts of a specific section, such as a sector, floor, facility, or subsystem of the building, of the mapped work environment.*

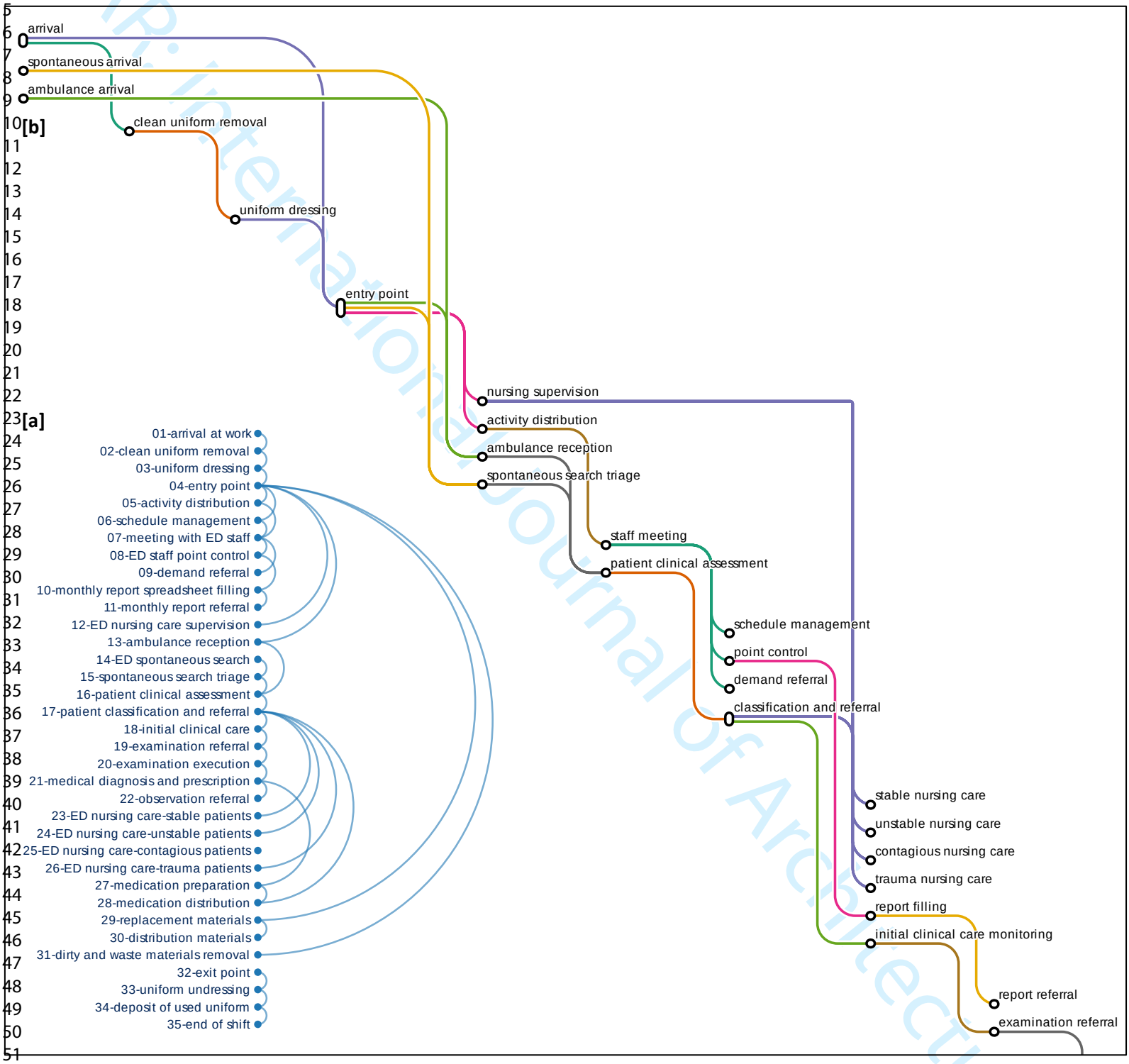
*Source: authors*

*Figure VI – matrixial mapping environmental and processual congruence*



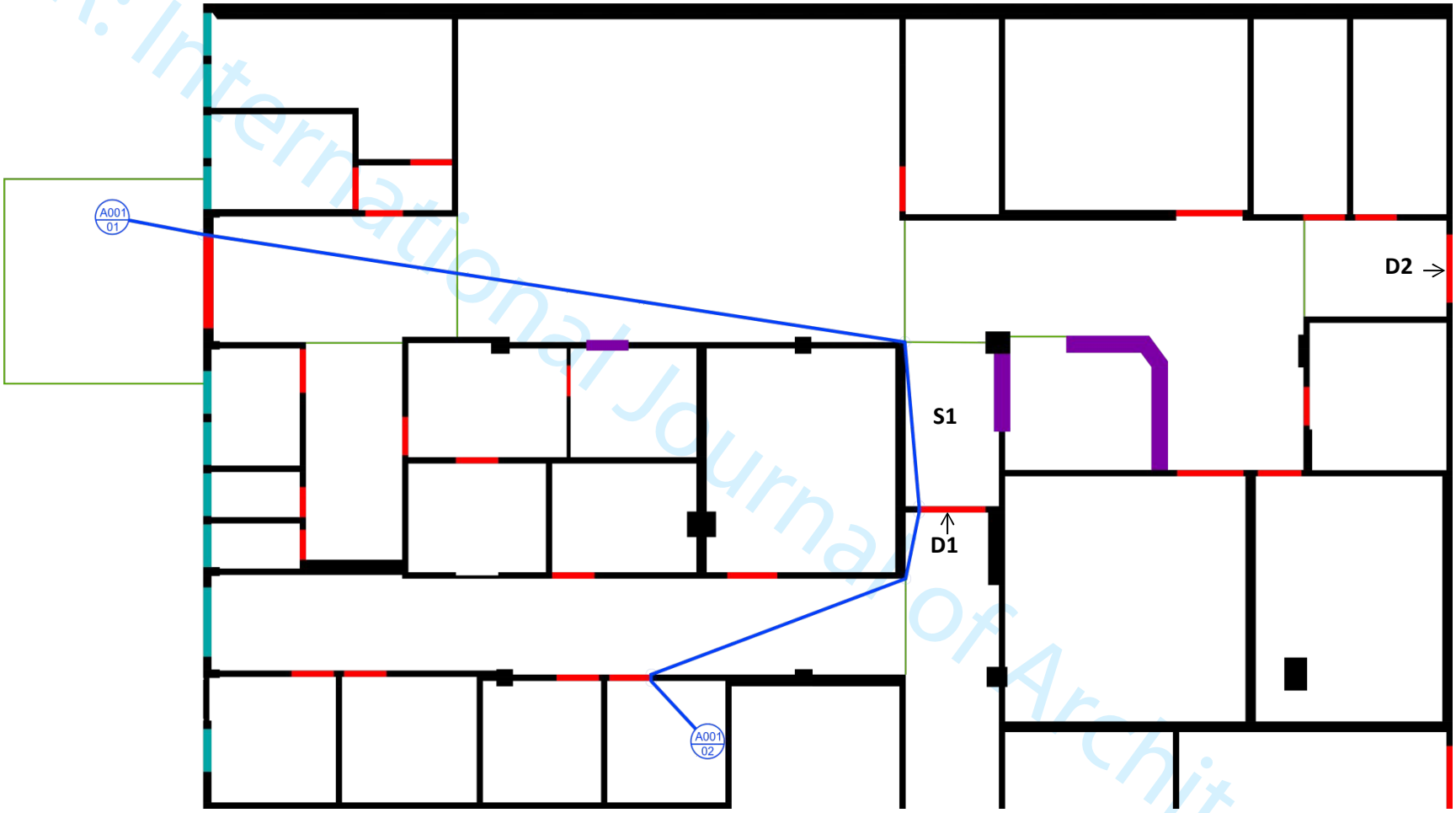

Source: authors, based in Pereira, Ornstein, Soares, et al (2023).

*Figure VII – sequencing and parallelism and priority in process flowcharts.*




*Note: nurse role activities in [a] linear and [b] stair-step sequence.*
*Source: authors, 'a' based in Bostock (2023), 'b' based in Abrate (2022).*

*Figure VIII – space allocation in floor plan, best-first path*




*Note / Legend: The picture was generated in PNG format; depicting areas within the emergency department. red lines represent doors; light blue lines indicate windows; violet lines denote counters; green lines mark the imagined boundaries of areas, and; black lines represent walls; blue path illustrates the optimal route for a hypothetical activity, which consists of two steps. Step 01 is situated under the exterior canopy, while step 02 takes place in a consultation room. In the event the user specifies that area S1 is restricted, thereby blocking access to Door D1, the program will seek the best route by passing through Door D2.*
*Source: authors*