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LEVERAGING DATA TO VISUALIZE AND ASSESS SPACE PLANNING COMPLIANCE

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Abstract: Space planning is a primary task during the schematic design process, to produce a geometric configuration of a space layout that is in accordance with the project's requirements. A critical challenge of space planning is the amount of data to be tracked, requiring designers to rely heavily on their memory to keep track of this information while developing layouts. The rigorous process of analyzing, structuring and extracting meaningful information often leads to requirements being overlooked or important requirements failing to be satisfied. Failure to meet the client's space plan requirements, could possibly lead to decline in the performance of the building, cost increase, client dissatisfaction and penalty fines. This research investigated the current practices and challenges of space planning requirements data management, and design workflow at a large-scale consulting firm. Following the case study and recording challenges, a smart Microsoft Excel® template was developed to structure and parse a client's space planning requirements data. This was essential to extract significant compliance requirements data from heavily unstructured and redundant documents. The types of compliance requirements data that were structured and parsed using this method include; location, access, adjacency, daylighting, and acoustic requirements (sound privacy). Following the extraction of essential requirements, a Microsoft Power BI® dashboard was developed to provide designers with an interactive, searchable dashboard that visualizes room adjacency criteria. In addition, a real-time assessment tool was developed using Revit® and Dynamo® to support design assessment by creating visual overlays on floor plans.

1 INTRODUCTION

Space planning is an iterative process that evolves according to the client's requirements (Kiviniemi 2005, Guo and Li 2017). A space plan frames the entirety of the building and has a major effect on whether the building will function well for the intended purpose and has existed since the beginning of architecture as an exploration of decision making for design (Cherry and Petronis 2016). Designers are expected to comply to an owner's requirement with a set of criteria and this can be a tough endeavor for designers as some building plan requirements may be complex (Guo and Li 2017). A designer constantly reiterates a space plan until it is sufficiently compliant with the client's requirement. This process generally entails a designer receiving space planning design information from clients in various formats and unstructured data sets during the early stages of design and manually analyzing it to make changes in the design software accordingly. Documents received from clients will generally contain key information about the functional program, such as room and department names, room areas, the function of each room, and the proximity between rooms. These requirements can be complex to analyze when developing a final space plan solution that is compliant with the client's requirements due to the interdependent relationship between rooms, spaces and departments (Guo and Li 2017). A critical challenge of space planning is the limitation in the link between the client's requirements and design tools (Chae 2017 and Yi 2016). This demonstrates the importance of leveraging data to further improve the compliance of space planning in accordance with the client's requirements.

2 BACKGROUND

Different researchers have developed algorithms to aid with solutions for space plan issues since the 1960's. However, the increasing complexity of design and construction in the last few decades and the significant reduction in time available for a project's preliminary conceptual design phase has changed the space planning design activity (Donato 2017). The constraint of space, decisions, information and specifications has served as a motivation for researchers to make developments towards space planning compliance (Yi 2016). This interdependency of functional requirements requires different deliberations by the designer and may cause a strain when they are complex. A change in one of the functions can result in a chain reaction, affecting many other functions (Park 2004). Yi (2016) developed a space layout tool to generate space layout geometry to evaluate "daylight level and room shading" to help architects make design changes accordingly. Das & Haymaker (2016) propose the use of "an emerging methodology and tool" that generates space plan designs known as Space Plan Generator (SPG) using Autodesk Dynamo® and Project Fractal®. They generate multiple designs using a hierarchical approach of placing departments first and then programs within the department, and finally circulation. Boon et al., (2015), used analytical tools Grasshopper and Galapagos to develop a script "to graphically represent and optimize the adjacency requirements in programmatic spaces". Guo & Li (2017) propose a method for "the automatic generation of a spatial architectural layout from a user-specified architectural program".

2.1 Background Conclusion

Space programming is recognized for being an important first step in schematic design as it is critical in dictating the functionality of the building project. Recent developments are adopting methodologies and tools of computer science for analysis, generation, and optimization of design. Although previous researchers have made developments that clearly link space programming requirements to the design process by automating visualizations, their methodologies have an end product where the adopted workflow and tool produce space programs with no room for manipulation by the designer. This leaves out the biggest impact player out of the workflow- *the designer*.

3 RESEARCH APPROACH

An observation-based empirical research approach was implemented for this case study. This research was performed over the course of one year at Stantec Consulting Ltd in Vancouver, British Columbia. Four projects with a range of project cost from $25 million to $1.4 billion were analyzed for this research. Each project was examined to a different extent- analyzing their statement of requirements, functional program, room data sheet, 3D models, addendums, request for proposal, mark-ups, space programming requirements data and populating their dRofus database resulting in over 193 hours of analysis.

4 DEVELOPMENTS

This section will discuss the developments that were made to support the compliance of a building project's space program with the client's requirements. Following the research conducted at the architectural firm, it was evident that the current workflow required enhancements to make the space programming process less tedious and to avoid the trial and error driven approach for designers. Three developments were made to optimize the current space programming workflow by leveraging the clients design requirements.

4.1 Smart Excel Template to Parse Space Programming Requirements Data

As a first step in this automation, space programming information needed to be exported from dRofus® - where the project requirements data was managed. The generated excel spreadsheet contained the room name, and 'Special Requirements' field which is where the space programming requirements data would be dumped along with other uncategorized requirements. A formula was then developed to parse the space program requirements data. Figure 1 illustrates the smart-excel template developed to structure and parse space programming requirements. Figure 2 shows the formulae developed for each cell to extract the space program requirements. Table 1 shows the words used in the Microsoft Excel formula to flag relationships between rooms.

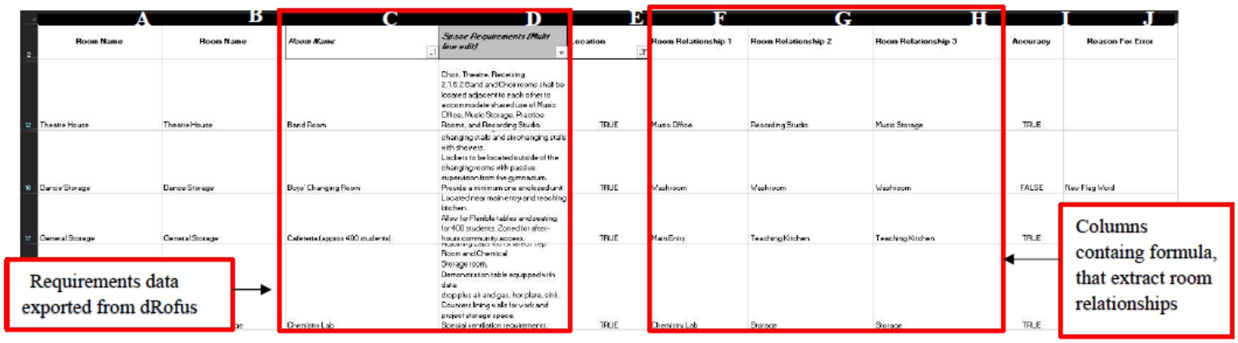

Figure 1 Excel Spreadsheet Structured for Parsing Requirements

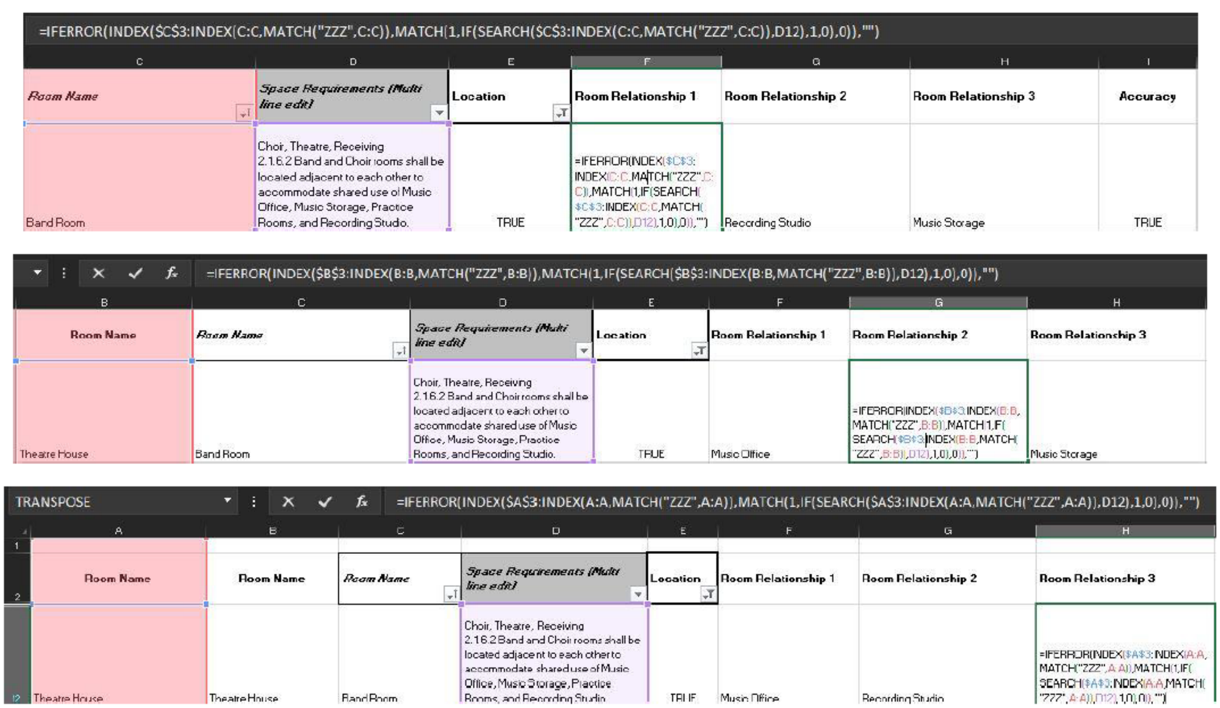

Figure 2 Formulae used to parse space program requirements

Table 1: Words Used in the Formula to Flag Relationships Between Rooms

Location	Adjacency	Access	Visibility
Locate	Adjacent	Direct Access	Visible
Located	Adjacency	Within	Visibility
Near	Positioned	Connected	Positioned for Supervision
Close to		Integrated into	Passive Supervision
			Positioned

4.2 Space Planning Requirements Dashboard Visualization

Once the space program requirements data were identified by the smart-excel template, a dashboard was developed for the 'Location', 'Adjacency', 'Access' and 'Visibility' requirements using Microsoft PowerBI®. This was developed to provide designers with an interactive, searchable dashboard that will provide them with a quick room interrelationships visualization for space programming requirements. Figure 3 shows the 'Location' space program requirements, visualized by the 'Force-Directed Graph' in conjunction with a 'Text Filter' feature in PowerBI®. When a user enters a search word for query, the graph filters down to all the rooms containing that search word along with the relationships it has with other rooms indicating a proximity requirement. The proximity requirement between two rooms are indicated when they are connected by a line as shown in Figure 3.

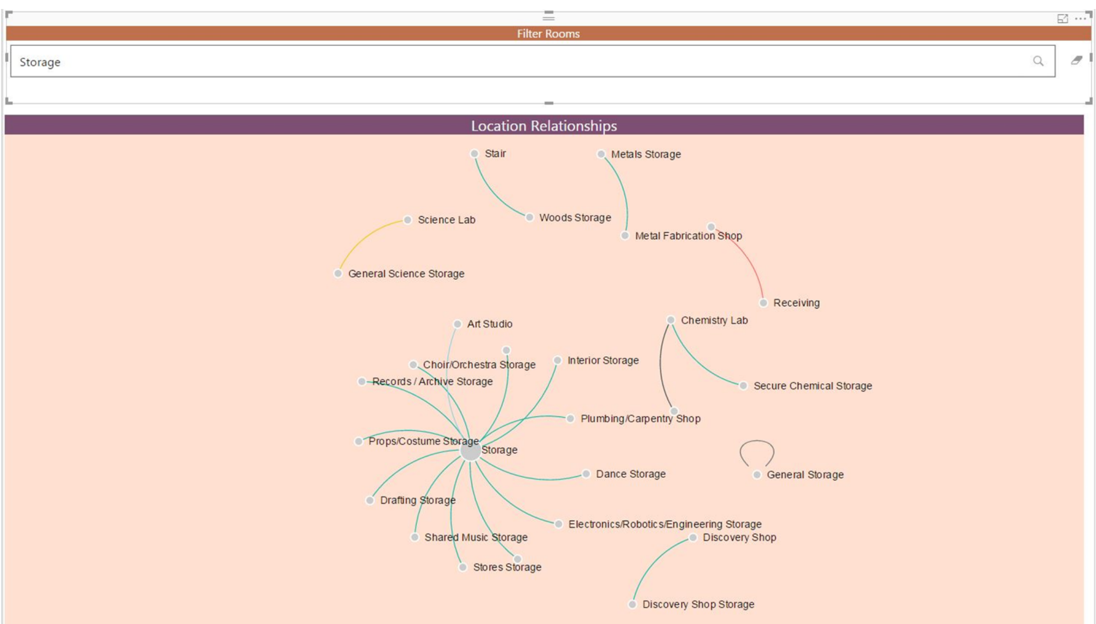

Figure 3 Searchable dashboard for location relationship requirements

The Power BI® dashboard was also used to indicate the accuracy of the parsing implemented in the smart excel template. The accuracy of the effort to identify the relationships between rooms by using the Microsoft Excel formula are shown in Figure 4. The accuracy of the parsing efforts was measured manually by reading all of the client's requirements and checking if the room relationship requirements were identified by the Microsoft Excel template. Once the incongruities were identified the spreadsheet was revised by fixing these errors manually to reflect 100% accuracy.

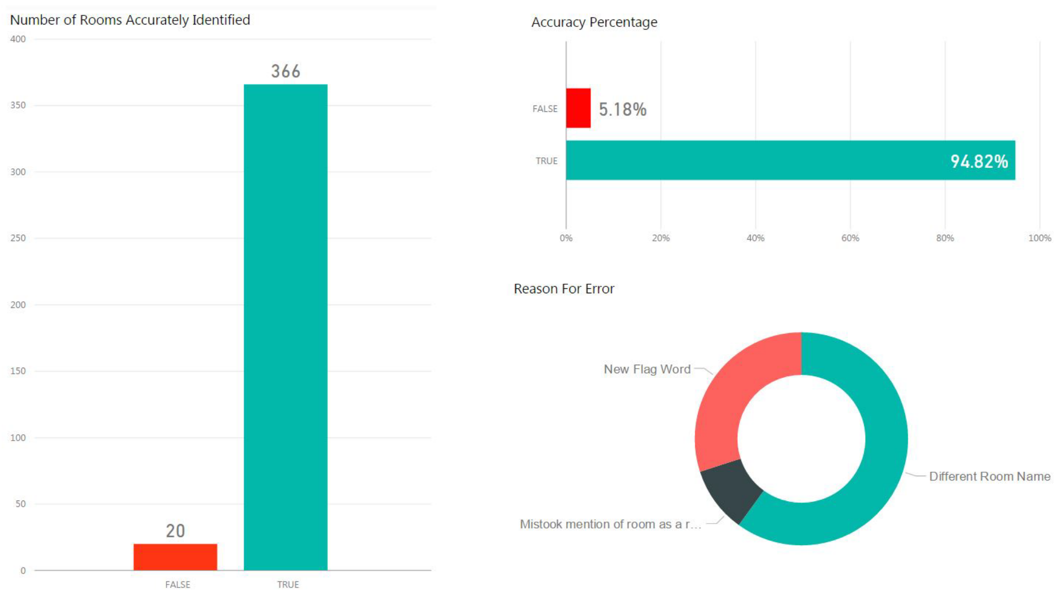

Figure 4 Location- Space Program Requirement Accuracy Statistics

4.3 Space Planning Requirements Floor Plan Visualization

BIM design tools Autodesk Revit® along with Autodesk Dynamo® were used to develop two visualization methods for the space program requirements, according to their type of requirement. The 'Daylight' and 'Acoustics' requirements were visualized using color schemes to represent the different requirements. Consequently, the requirements such as 'Location', 'Adjacency', and 'Access' which indicate proximity relationships between rooms, were identified by drawing lines between room centroids.

4.3.1 Daylight

Daylight affects where a room is located and its orientation, depending on whether it requires direct or indirect sunlight. For instance, in Project A, this indicated that a room requiring direct daylight, such as the Gymnasium, could not be placed in the center of the project site where other buildings may be an obstruction from direct daylight. Figure 5 & 6 show the Daylight requirements visualizations as an overlay on the Revit® architectural floor plan produced by the Dynamo® script.

Figure 5 First Floor Daylight Requirements Compliance Assessment Visualization

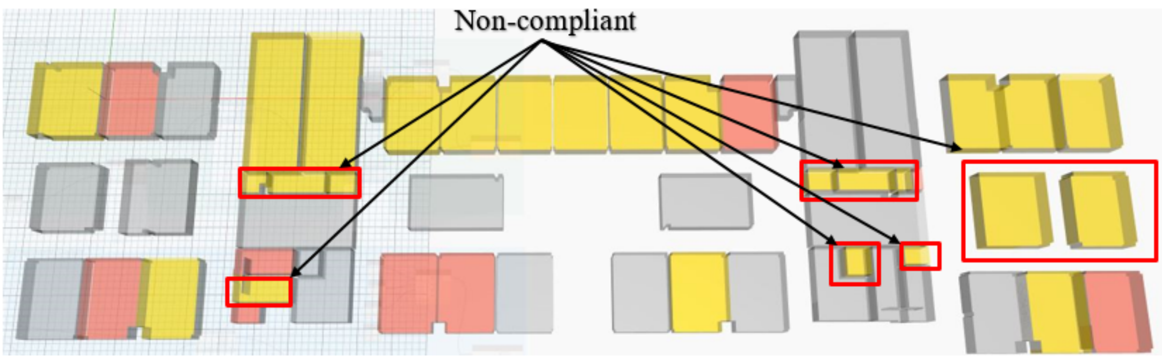

Figure 6 Second Floor Daylight Requirements Compliance Assessment Visualization

According to this assessment method, rooms that are non-compliant with the client's requirements can be seen in Figure 6. This is because they are placed in the center of the project site where they are obstructed from direct daylight. This provides a simple visualization for the designer to revaluate the design and make changes.

4.3.2 Acoustics

The acoustics space program requirement refers to a room placement according to sound and noise ratings. For this project it meant rooms such as the Metal Fabrication Shop, that produce high noise due to activities such as carpentry and welding cannot be located near rooms such as classrooms or the library. Figure 7 & 8 show the Acoustics requiremen visualizations as on overlay on the Revit® architectural floor plan produced by the Dynamo® script.

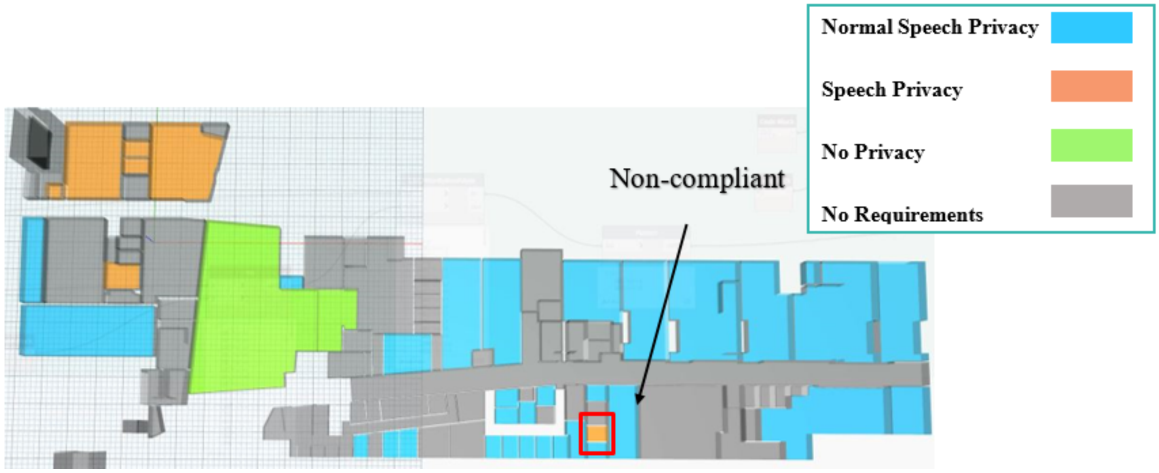

Figure 7 First Floor Acoustics Requirements Compliance Assessment Visualization

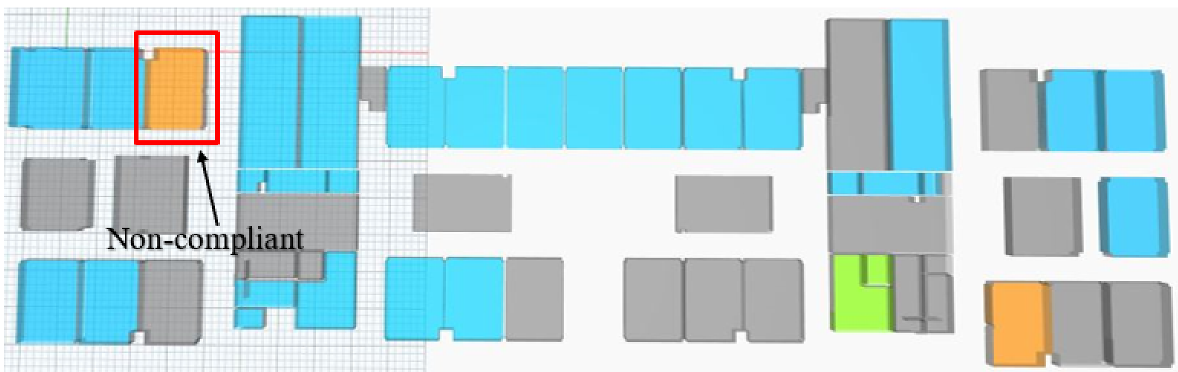

Figure 8 Second Floor Acoustics Requirements Compliance Assessment Visualization

According to this compliance validation method, there are two non-compliant rooms for acoustics requirements on the first and second floor (see Figure 7 & 8). The rooms indicated in orange shading exert noise that the rooms indicated in blue would be undesirably affected by.

Figure 9 illustrates the script developed in Dynamo® to assess the space program requirements for Daylight and Acoustics space program requirements.

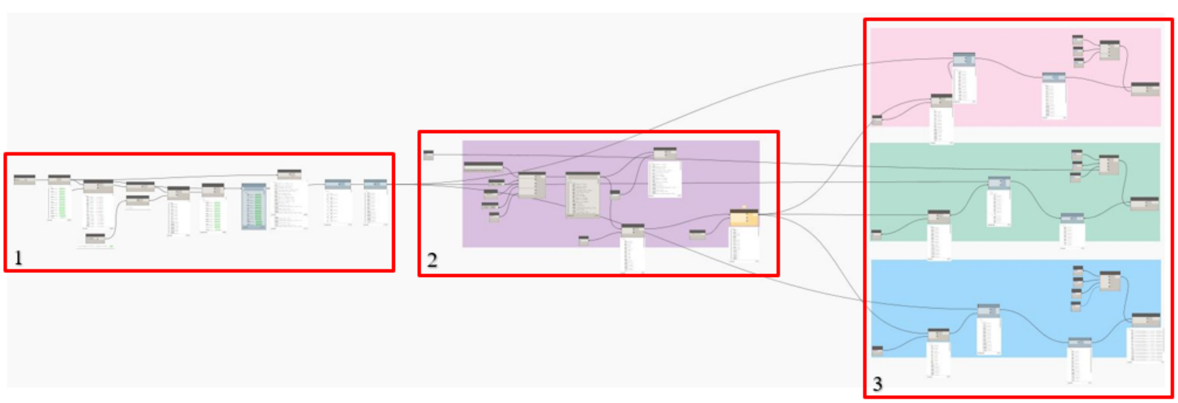

Figure 9 Dynamo Script for Daylight and Acoustics Space Program Compliance Assessment

4.3.3 Location

This requirement conforms to the location of a room in proximity to another, limited by a certain amount of distance. This distance however is not defined and often referred to by words such as “close to” and “near”. The black dotted lines projected onto the floorplan are produced to assess the space program requirements by running the Dynamo® script, within the Revit® architectural model.

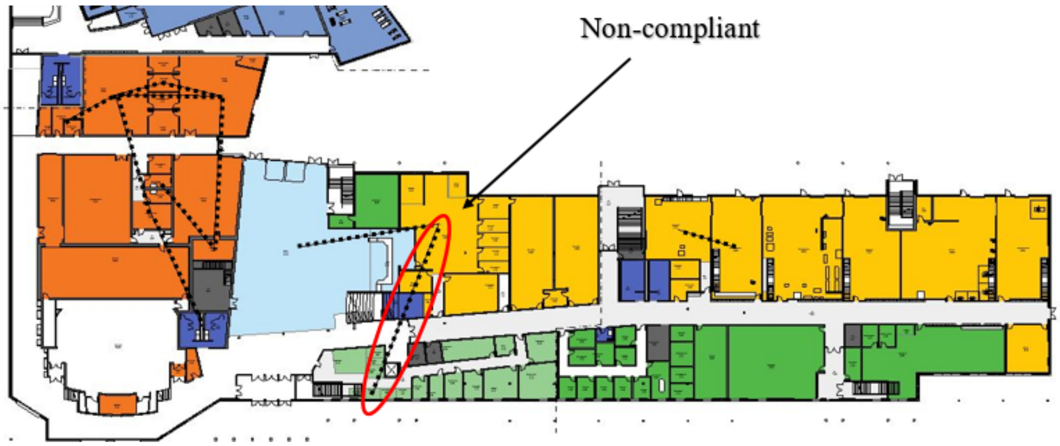

Figure 10 Location Requirement Space Program Compliance Assessment- First Floor

4.3.4 Adjacency

The adjacency space program requirement entails for a room to either share a common wall, or vertex with another room. The script was developed to draw the validation lines from one room centroid to another, however the lines circled in red indicate that one side of the line is not attached to a room centroid and is left hanging. This indicates that the rooms with an adjacency requirement have been placed on different floors.

Figure 11 Adjacency Requirement Space Program Compliance Validation First, Second and Third Floor

4.3.5 Access

The space program's access requirement, requires for a room to have direct access to another room, usually conformed by the two rooms sharing a mutual door. Access had the most instances of space program requirements in the SOR and was deemed the most important by the designers.

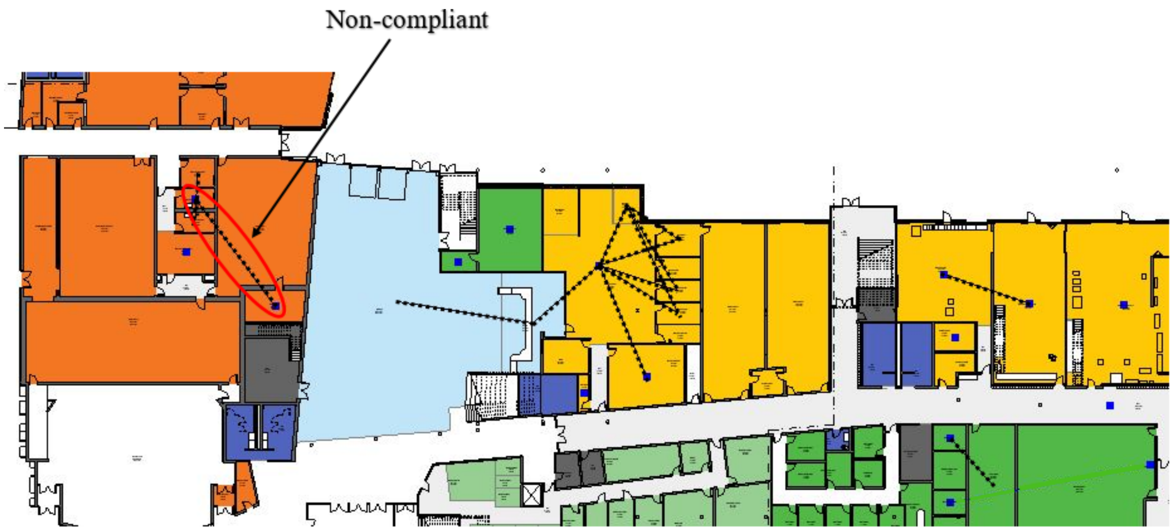

Figure 12 Access Requirement Space Program Compliance Assessment- First Floor

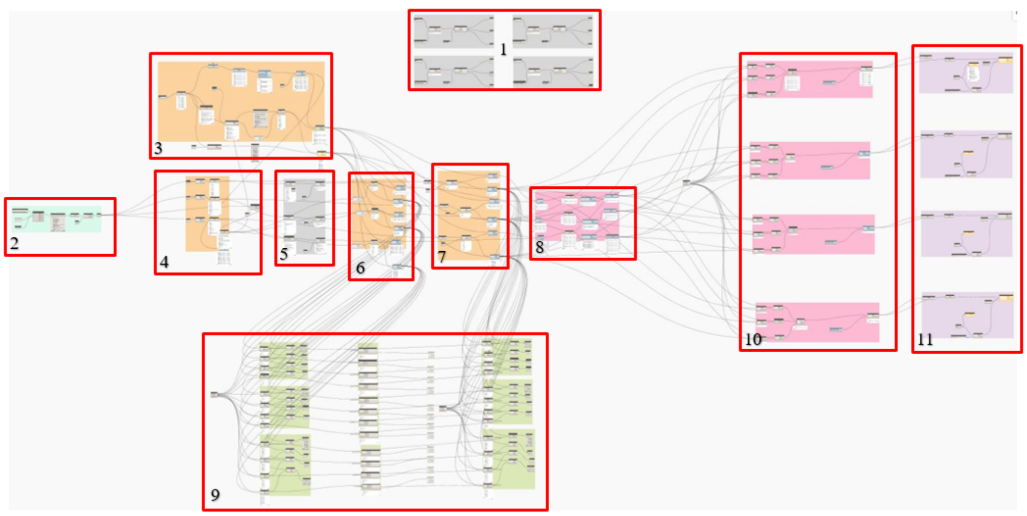

Figure 13 Dynamo Script for Location, Adjacency and Access Space Program Compliance Validation

5 CONCLUSIONS

In this research, a case study was conducted to investigate the current practices of space program requirements data management, and design workflow in a large architectural firm. By closely following project data managers and designers, their workflow was recorded, and space programming requirements documents were analyzed. Four projects were studied, and a total of 193 hours were spent analyzing and populating project data into dRofus®. This was implemented to investigate the extent to which computational tools could be used to validate the compliance of a building project's space program requirements. The evaluation and assessment of the space programming requirements was carried out by using Autodesk Revit® and Dynamo® to produce a visual overlay on the architectural model's floor plan. This workflow received a highly positive response from the designers at the large scale architectural/engineering firm. The designers estimated that 10-25% of preliminary design time could be saved with this workflow. It was also concluded that evidently not all building projects have complex space programming requirements. The time and cost required to structure the database and manipulate the Dynamo® script could be significant and outweigh the value of the space programming visualizations developed. The developments made during this research must be used on projects with complex space programming requirements in order to gain optimal benefits from the efforts required. Consequently, BIM technology and related tools can play a profound role in the entire process of assessing space programs according to a client's needs and requirements. The visualizations were produced under the presumption that they would:

- Allow for designers to evaluate project space programs without having to manually analyze client's requirements.
- Save cumbersome space program design time by eliminating the trial and error process as recorded in this study.
- Eliminate the need for designers to rely on their memory of the space program requirements and jeopardize accuracy and instead run the Dynamo® script for evaluation.
- Save the firm penalty fines that arise from space program requirements incompliance.

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