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ALTINBAŞ UNIVERSITY
Institute of Graduate Studies
Architecture

**ANALYSIS OF THE INTERACTION OF
SPACES IN THE INDUSTRIAL BUILDING
DESIGN WITH SPACE SYNTAX METHOD**

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Master's Thesis

Supervisor

Asst. Prof. Dr. Can UZUN

Istanbul, 2023

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2023

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I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

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Signature

DEDICATION

I dedicate this thesis to my family members who have supported me on this path, especially to my devoted father who has been my life's inspiration and first and finest teacher. My dear wife, Kimia, for her love, emotional support, patience, and understanding amid the difficulties of graduate school and life, my dedicated mother, for his unconditional love, unending support throughout my life, and encouragement for further education.



PREFACE

I want to thank and appreciate my dear advisor, Assistant Professor Dr. Can UZUN. His encouragement and direction made it possible for me to bravely start my academic career.

I would also like to express my gratitude to my committee members, who went above and beyond their roles as teachers and committee members by offering advice, compassion, and support.

And lastly, many thanks to my friends who stood by me during this drawn-out process.



ABSTRACT

ANALYSIS OF THE INTERACTION OF SPACES IN THE INDUSTRIAL BUILDING DESIGN WITH SPACE SYNTAX METHOD

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Date: April / 2023

Pages: 89

Industrial buildings, particularly factories, require careful consideration in terms of their spatial configuration and integration. The natural user movement and connectivity within these buildings have a significant impact on their functionality and efficiency. Therefore, in this research, the aim is to analyze the integration of spaces in industrial buildings, with a specific focus on factories, in terms of connectivity and natural user movement. To achieve this objective, the space syntax method is employed, which is commonly used for space analysis. Firstly, the concept of space syntax is explained and how it is utilized in space analysis. Secondly, the significance of circulation and spatial configuration in industrial buildings is emphasized, particularly in factories. The analysis is conducted using the Depthmap X software, in both furnished and unfurnished cases, to analyze the different spaces within the factory. The software produces visual maps that illustrate the connectivity and natural user movement within the building. The analyzed results were obtained using logical reasoning, and all explanations are based on the visual data obtained. This research investigates the impact of furniture on the circulation and connectivity of spaces in industrial buildings. The different spaces are analyzed within the factory and produce visual maps that illustrate the connectivity and natural user movement within the building. The flow density of different areas is investigated, and it is observed how it is affected by the intersection of circulation from other spaces. In conclusion, this research sheds light on the importance of

the spatial configuration and integration of spaces in industrial buildings, particularly in factories. The analysis using the space syntax method and Depthmap X software provides valuable insights into the natural user movement and connectivity within the building. By investigating the impact of furniture on circulation and connectivity, it contributes to the literature on industrial building design, highlighting the significance of efficient spatial configurations in enhancing their functionality and efficiency.

Keywords: Space Syntax, Industrial Buildings, Natural User Movement Analysis, Connectivity Analysis.



TABLE OF CONTENTS

	<u>Pages</u>
ABSTRACT	vii
LIST OF FIGURES.....	xiii
1. INTRODUCTION	1
1.1 IMPORTANCE OF SPATIAL COGNITION ON ARCHITECTURAL DESIGN ...	1
1.2 SPACE SYNTAX.....	1
1.3 MOVEMENT CIRCULATION IN INDUSTRIAL BUILDINGS	2
1.4 RESEARCH QUESTION AND GOALS	3
1.5 RESEARCH METHODOLOGY	3
2. AN OVERVIEW ON THE CONCEPT OF SPACE SYNTAX IN THE FIELD OF ARCHITECTURE	5
2.1 THE CONCEPT OF SPACE SYNTAX.....	5
2.2 GRAPH THEORY.....	6
2.3 EXPLANATORY DIAGRAM AND SPATIAL ORDER	7
2.4 INDICATORS OF SPACE STRUCTURE ANALYSIS USING SPACE SYNTAX METHOD	8
2.4.1 Connection	8
2.4.2 Integration	9
2.4.3 Depth.....	11
2.4.4 Accessibility.....	11
2.4.5 Natural movement.....	12
2.5 SAMPLE: COLLEGE OF ARCHITECTURAL ENGINEERING.....	14
2.5.1 Selection of a Case Study and its Description	14
2.5.2 Analysis of Glazing's Effects on Function Using VGA (Figure 2.9)	16
2.5.3 Analysis of Glazing's Effects on Function Using VGA (Figure 2.10)	16
2.5.4 Axial Analysis is Discussed (Figure 2.11).....	17
2.5.5 Axial Analysis is Discussed (Figure 2.12).....	18
2.6 SAMPLE: INTRODUCTION OF CHONGQING IRON & STEEL PLAN.....	19

2.6.1 Local Integration Analysis	20
2.6.2 Connectivity Analysis	21
2.6.3 Depth Analysis	22
2.6.4 Space Attribute Analysis of Outdoor Plazas	23
2.7 SAMPLE: DESIGN PRACTICE IN BUILDING CONTEXT: TATE BRITAIN	24
2.7.1 Comparative Analyses	25
2.7.2 Visibility Graph Analyses	25
3. INDUSTRIAL BUILDINGS.....	28
3.1 DEVELOPMENT FACTORS OF INDUSTRIAL BUILDINGS	28
3.2 DEFINITION OF INDUSTRIAL BUILDINGS	29
3.3 INDUSTRIAL ARCHITECTURE'S KEY ELEMENTS	30
3.4 TYPES OF INDUSTRIAL BUILDINGS	30
3.4.1 Warehouse.....	30
3.4.2 Manufacturing.....	31
3.4.3 Light Manufacturing	33
3.4.4 Refrigeration	33
3.4.5 Telecom and Data Hosting Centers	35
3.4.6 Flex	35
3.4.7 Showroom	36
3.4.8 Research and Development.....	37
3.4.9 Biotechnology	38
3.5 THE IMPORTANCE OF FACTORY ARCHITECTURE AND DESIGN	40
3.6 THE PHILOSOPHY OF MACHINES AND EQUIPMENTS IN THE FACTORY	40
4. CASE STUDIES	42
4.1 NITRILE GLOVE MANUFACTURING FACTORY	43
4.1.1 Ground Floor Connectivity Analysis without Furniture	45
4.1.2 Ground Floor Connectivity Analysis with Furniture	46
4.1.3 First Floor Connectivity Analysis without Furniture.....	47

4.1.4 First Floor Connectivity Analysis without furniture.....	48
4.1.5 Second Floor Connectivity Analysis without Furniture	50
4.1.6 Second Floor Connectivity Analysis with Furniture	52
4.1.7 Ground Floor Natural Movement Analysis without furniture	53
4.1.8 Ground Floor Natural Movement Analysis with furniture	54
4.1.9 First Floor Natural Movement Analysis without furniture	55
4.1.10 First Floor Natural Movement Analysis with Furniture	56
4.1.11 First Floor Natural Movement Analysis without Furniture	58
4.1.12 First Floor Natural Movement Analysis with Furniture	59
4.2 TEXTILE PRODUCTION FACTORY	61
4.2.1 Main Office Area Connectivity Analysis without Furniture	62
4.2.2 Production Areas Connectivity Analysis without Furniture	63
4.2.3 Storage Areas Connectivity Analysis without Furniture	65
4.2.4 Main Office Area Connectivity Analysis with Including Furniture	66
4.2.5 Production Areas Connectivity Analysis with Including Furniture.....	67
4.2.6 Storage Areas Connectivity Analysis with Including Furniture	69
4.2.7 Main Office Area Natural Movement Analysis without Furniture.....	70
4.2.8 Production Areas Natural Movement analysis without furniture	71
4.2.9 Storage Areas Natural Movement Analysis without Furniture.....	71
4.2.10 Main Office Area Natural Movement Analysis with Including Furniture	72
4.2.11 Production Areas Areas Natural Movement Analysis with Including Furniture	73
4.2.12 Storage Areas Natural Movement Analysis with Including Furniture	73
5. CONCLUSION	75
5.1 COMPARISON OF THE VISUAL MAPS IN TERMS OF INCLUDING AND EXCLUDING FURNITURE IN FACTORY SPACES (NITRILE GLOVE FACTORY)	75
5.1.1 Ground Floor Connectivity Comparison Table	75
5.1.2 First Floor Connectivity Comparison Table	76

5.1.3 Second Floor Connectivity Comparison Table.....	77
5.1.4 Ground Floor Natural Movement Comparison Table.....	78
5.1.5 First Floor Natural Movement Comparison Table.....	79
5.1.6 Second Floor Natural Movement Comparison Table	80
5.2 COMPARISON OF THE VISUAL MAPS IN TERMS OF INCLUDING AND EXCLUDING FURNITURE IN FACTORY SPACES (TEXTILE PRODUCTION FACTORY)	81
5.2.1 Connectivity Comparison Table	81
5.2.2 Natural Movement Comparison Table.....	83
REFERENCES	86



LIST OF FIGURES

	<u>Pages</u>
Figure 2.1: Taken From the Book "Space is a Machine", 2007.	8
Figure 2.2: Sample Case of Connectivity Analysis.....	9
Figure 2.3: Sample Case of Integration Analysis-Global Choice Pattern.	10
Figure 2.4: Example of Spatial Accessibility Models Created Using Space Syntax.	12
Figure 2.5: The Logic of The Theory of Natural movement, Source: Hillier, 1993.	13
Figure 2.6: Agent Movement Based Model.	14
Figure 2.7: Plans for the College of Architectural Engineering & Digital Design - DAU, KSA, shown in an Illustrative Manner.	15
Figure 2.8: Interior Photos for CADD Transition Spaces Display Glazed Partitions on Both Sides of the B and C Spaces that Serve as a Physical and Acoustic Barrier and Maintain Visual Consistency for Classes.....	15
Figure 2.9: Analysis of the Visual Integration in Cases X and Z in Comparison.	16
Figure 2.10: Analysis of the Visual Choice in Cases X and Z in Comparison.	17
Figure 2.11: Integration and Selection Measurements are Used in the Axial Analysis for Case X.	18
Figure 2.12: Integration and Selection Measurements are Used in the Axial Analysis for Case Y.	19
Figure 2.13: The Transformation Plan's Schematic Diagram.	20
Figure 2.14: Analyses of Local Integration in Convex Space.....	21
Figure 2.15: Convex Space Connectivity Analysis.	22
Figure 2.16: Convex Space Depth Analysis.....	23

Figure 2.17: Movement Traces and Vga Analyses in Existing Museum.....	26
Figure 2.18: Testing Three Design Proposals.	27
Figure 3.1: Industrial Building.	28
Figure 3.2: High-loading dock doors at the Getagadget Warehouse.....	31
Figure 3.3: Manufacturing Buildings.	32
Figure 3.4: Refrigerated Warehouse.....	34
Figure 3.5: Vantage Data Centers Buys Hyper scale Data Center Business in Montreal. ..	35
Figure 3.6: Location of Shushtar city in Iran.....	36
Figure 3.7: Showroom building on Behance.	37
Figure 3.8: Research and Development Building.....	38
Figure 3.9: Warsztat Architektury, Faculty of Biotechnology Building.....	39
Figure 3.10: Alamance Community College Accelerates Investment in Biotech.	39
Figure 4.1: General Arrangement of Different Spaces on the Ground Floor.	44
Figure 4.2: General Arrangement of Different Spaces on the Ground Floor. (First Floor).44	
Figure 4.3: General Arrangement of Different Spaces on the Ground Floor (Second Floor).	45
Figure 4.4: Ground Floor of the Factory (Unfurnished Connectivity Analysis).	46
Figure 4.5: Ground Floor of the Factory (Furnished Connectivity Analysis).	47
Figure 4.6: First Floor of the Factory (Unfurnished Connectivity Analysis).....	48
Figure 4.7: First Floor of the Factory (Furnished Connectivity Analysis).....	50
Figure 4.8: Second Floor of the Factory (Unfurnished Connectivity Analysis).	51
Figure 4.9: Second Floor of the Factory (Furnished Connectivity Analysis).	53

Figure 4.10: Second Floor of the Factory (Unfurnished Natural Movement Analysis).....	54
Figure 4.11: Ground Floor of the Factory (Furnished Natural Movement Analysis).	55
Figure 4.12: First Floor of the Factory (Unfurnished Natural Movement Analysis).	56
Figure 4.13: First Floor of the Factory (Furnished Natural Movement Analysis).	57
Figure 4.14: Second Floor of the Factory (Unfurnished Natural Movement Analysis).....	59
Figure 4.15: Second Floor of the Factory (Furnished natural Movement Analysis).....	61
Figure 4.16: General Map of the Factory.	62
Figure 4.17: Unfurnished Connectivity Visual Map Analysis of the Factory.....	63
Figure 4.18: Furnished Connectivity Visual Map Analysis of the Factory.....	68
Figure 4.19: Unfurnished Natural Movement Visual Map Analysis of the Factory.	70
Figure 4.20: Furnished Natural Movement Visual Map Analysis of the Factory.	72
Figure 5.1: Connectivity Comparison Table -Ground Floor.	75
Figure 5.2: Connectivity Comparison Table -First Floor.	76
Figure 5.3: Connectivity Comparison Table -Second Floor.	78
Figure 5.4: Natural Movement Comparison Table -Ground Floor.	79
Figure 5.5: Natural Movement Comparison Table -First Floor.	80
Figure 5.6: Natural Movement Comparison Table -Second Floor.....	81
Figure 5.7: Connectivity Comparison Table-Second Floor.	82
Figure 5.8: Natural Movement Comparison Table-Second Floor.....	83

1. INTRODUCTION

1.1 IMPORTANCE OF SPATIAL COGNITION ON ARCHITECTURAL DESIGN

Problems due to the user behavior that exists in architectural spaces, including congestion, loneliness and abandonment of some parts. Those which itself affects concepts such as spatial quality and security and tranquility of the architectural space. It depends on factors such as the body of the architectural space. The theory of spatial arrangement seeks to establish a causal relationship in human societies (Bafna, 2003). One of the foundations of this theory is that in contrast to the physical properties of space, it is the configuration properties of space that have a direct impact on shaping human activities (Vaghaun, 2008). In other words, the division of the population is always related to the degree of interconnectedness of the spaces.

1.2 SPACE SYNTAX

The Space Syntax method was first introduced by Steadman Bill Hillier and Julian Hansen in the early 1970s, opening a new chapter in morphology in architecture. In the book "Architectural Morphology", Stedman (1970) deals more with the theoretical foundations of architectural morphology. In simple terms, Stedman compares the geometric composition of different spaces of a building with different possible combinations. For example, he examines all available combination possibilities of a room and a corridor, and introduces among them which has a more realistic functional logic and appearance.

Hillier and Hansen (1970) believe that they have gone beyond theoretical studies and given them a practical aspect. The first phase of their work in the 1970s involved real environments, indigenous buildings, and organic complexes. Hillier and Hansen's (ref) main concern was to find the productive factors, and hidden patterns or genotypes that were beyond the spatial forms. The second stage of the development of the syntax method of space occurred in the eighties. To achieve their goal, Hillier and Hansen (ref) presented a drawing technique called justification diagrams. This drawing method allowed them to simulate different spatial patterns.

Space Syntax is a set of methods and theories that study the configuration of space, on architectural and urban scale. Space syntax method is to understand how the configuration

spatial structure occurs, and how a social organization interacts with this spatial structure. Syntax means examining the relationship of each spatial unit in an adjacent space set, just as examining a word within a text and relating it to other words (Hillier, 2007). If an object is considered to be composed of a spatial communication system, the appearance of this communication system will be in the form of a plan (Jamshidi, 2003). Recognizing these patterns and design means recognizing the social relationships that occur within spaces. Understanding social relations in spaces is of paramount importance, rather than the general form or shape of space. The proponents of the Space Syntax method believe that social relations in space can be well understood and analyzed by utilizing space syntax (Hillier B, Leaman A, Stansall P, Bedford M, 1976).

1.3 MOVEMENT CIRCULATION IN INDUSTRIAL BUILDINGS

Circulation in industrial buildings refers to the movement of people and goods within the building. Industrial buildings often have large spaces with heavy machinery and equipment, making it important to design an efficient circulation plan that ensures the safety of workers and the smooth flow of materials.

Here are some key considerations for designing circulation in industrial buildings:

- a. **Separate pedestrian and vehicular traffic:** Pedestrians and vehicles should have separate designated routes to avoid accidents. This can be achieved by creating clearly marked walkways and using physical barriers such as bollards or guardrails.
- b. **Minimize congestion:** The design should aim to minimize congestion by providing enough space for movement and using one-way traffic flows where appropriate.
- c. **Provide clear signage:** Clear signage can help workers and visitors navigate the building and avoid getting lost. Signage should be visible from a distance and placed at strategic points such as intersections and entrances.
- d. **Ensure accessibility:** Accessibility is important for workers and visitors with disabilities. Circulation design should take into account the needs of these individuals and provide adequate space for wheelchair users.
- e. **Provide emergency exits:** Emergency exits should be clearly marked and easily accessible. They should also be positioned in a way that enables quick and safe evacuation of the building in the event of an emergency.

- f. Provide adequate lighting: Adequate lighting is essential for safe movement within the building, particularly in areas where workers are operating heavy machinery.
- g. Minimize noise and vibration: Industrial buildings can be noisy and produce vibrations that can be uncomfortable or even harmful for workers. Circulation design should take into account noise and vibration reduction measures to ensure a safe and healthy working environment (Teicholz E, 2001).

1.4 RESEARCH QUESTION AND GOALS

Examining the relationship between spaces due to the partition walls, openings, and location of the furniture or machines in industrial buildings (including factories and warehouses) by using the Space Syntax method is considered in this research. It can be observed how these factors are effective on user movements, connectivity, and even integration of the spaces.

The obtained results based on the graph theory and user movement behaviors are examined in cases, and these factors will be raised as a result of the research questions as follows:

How does the placement of the machines, furniture, and spatial configuration affect factors such as connectivity of spaces and user's movement behavior in that area?

What is the relation between Agent movement and connectivity indicators in industrial building spaces, by the results of space syntax analysis?

1.5 RESEARCH METHODOLOGY

In this study, space syntax methodology is utilized as the analysis method. The research method is applied in terms of its purpose, and in terms of its nature. This combination of simulation and descriptive analysis is called Space Syntax. Finally, according to the results of the analysis, logical reasoning has been generated.

In the data collection process; there were two different industrial building plan schemes which were drawn in a CAD software, have been selected for evaluation. In this way, the 2D spatial structure data of two selected industrial buildings were obtained.

The plan of case studies is analyzed and evaluated in terms of Connectivity and Natural user movement analysis by Depthmap X software. Depthmap X is a software tool that is commonly used for spatial analysis and network connectivity. The software can be used to

analyze the natural movement patterns of people within a space, and to identify potential connectivity issues that may be impacting the flow of people through the space. One technique for analyzing connectivity using Depthmap X is the use of visibility graphs. Visibility graphs are graphical representations of the direct and indirect lines of sight between different locations within a space. In this research, finally, by producing analytical maps (visibility graphs) and related tables, the results are investigated and analyzed by using the logical reasoning method. ([Applying space syntax Space Syntax – Online Training Platform](#)).

The aim of this research is to check how the furniture in industrial buildings affect the connection points and user movement behavior in those types of buildings. Also, the relation between connectivity and natural user movement graphs and table results will be considered as the assessment case.

2. AN OVERVIEW ON THE CONCEPT OF SPACE SYNTAX IN THE FIELD OF ARCHITECTURE

2.1 THE CONCEPT OF SPACE SYNTAX

Space syntax is one of the methods used in analyzing the spaces of buildings and city areas. Space Syntax is a collection of methods and theory to study the configuration of space in architectural and urban scale. Syntax means studying the relationship of each spatial unit in a set of neighboring spaces, just like studying a word inside a text and its relationship with other words. If a building is considered a complex object of a spatial communication system, the appearance of this communication system will be in the form of a plan. Knowing these designs and patterns means knowing the social relations that happen inside the spaces. Understanding social relationships in spaces is of primary importance, rather than the overall shape of the space. Finally, it is believed that social relations in space can be well understood and analyzed by using the space syntax method.

Genotype, which may be called a hidden pattern, refers to the abstract rules hidden in a spatial form. Phenotype is the body of a building that shows itself in the form of a species. Understanding one's genotype means understanding the social structure, the connections between components, the pattern of systematic activities and the semantic load of spatial relations. Phenotype, which is the same body type, can be changed in various forms, while it is possible to have a genotype in these various forms (Memarian, 2006).

This theory is an approach that examines the relationship between the body, space and current events in it and presents the results in the form of graphical and mathematical data. The theory of space syntax as one of the architectural research systems in the book of methods the architectural research of Linda Grote and David Wong (2002) has mentioned that it has been considered more than other theories in contemporary architecture. This method has been used by architects and designers such as Norman Foster and Richard Rogers (Yazdanfar, 2008). Space layout generally uses three theories in the field of philosophy, human geography and mathematics, benefits from related software for modeling and calculations and performs analysis with the help of indicators. The role of the computer in the modeling and analysis stage is very influential and unavoidable. In the field of philosophical foundations, we should mention the new philosophy as the foundation of this

theory. In this regard, Jamshidi points to the positivist essence of the theory of space arrangement and states that its approach to urban phenomena and spaces is influenced by the logic and thinking of logical positivism and Wittgenstein's ideas in it is a logical-philosophical treatise. And also in the field of geographical basics, he explains about the concept of space in this theory, which means open spaces such as streets, markets, rooms and corridors, etc., which are separated by visual and movement barriers such as walls. In the field of mathematics, he refers to discrete mathematics as the basis of this theory, which consists of various branches such as combinatorial mathematics, complexity and graph theory, which have many potential capacities (Jamshidi, 2003).

2.2 GRAPH THEORY

One of the tools of space analysis using this method, explanatory diagrams It is based on graph theory. In this way, each environment is a node and the connection between both spaces is drawn as a line connecting two nodes. This graph shows the theory of plan structure in a simple and readable way (Brown, Bellal, 2011). Graphs are summaries of the structural aspects of the model and simulate the network in the form of mathematics (Brandes, Erlebach, 2005). Visual graphs are an essential part of graph theory, as they provide a way to represent complex mathematical structures in a way that is easy to understand and analyze. In a visual graph, vertices are represented as points or dots, while edges are represented as lines or arcs that connect the vertices (Jonathan L. Gross and Jay Yellen, 2018).

Here are some other types of graphs used in space syntax analysis:

- a. Axial map: An axial map is a representation of the main paths or "axial lines" of a street network, which connect places of high accessibility and centrality. The axial map is constructed by extracting the most important streets or pedestrian paths from a street network and organizing them into a graph (Hillier,1996).
- b. Depthmap: A depthmap is a representation of the "depth" or accessibility of different parts of a space. It is constructed by measuring the distance and number of connections between each point in the space and all other points. Depthmaps can be used to analyze the accessibility and centrality of different areas, and to identify potential barriers to movement and social interaction (Hillier, 1996).

- c. Integration graph: An integration graph represents the degree of integration or connectivity between different parts of a city or building. It is constructed by measuring the number of direct and indirect connections between each point in the space and all other points. Integration graphs can be used to analyze the degree of fragmentation or integration of urban or architectural layouts, and to identify potential areas for improvement (Hillier, 1996).
- d. Convex map: A convex map is a representation of the degree of convexity or concavity of a space. It is constructed by measuring the degree of curvature of the space at each point and organizing the points into a graph. Convex maps can be used to analyze the spatial complexity and visual interest of a space, which can affect pedestrian movement and social interactions (Hillier, 1996).

2.3 EXPLANATORY DIAGRAM AND SPATIAL ORDER

Spatial order can be analyzed with the space syntax method. The meaning of spatial arrangement; The way spaces are arranged next to each other is their mutual relationship. Explanatory diagrams in the space syntax method are explained in the book "Space is a Machine" by Bill Hillier, but for a better understanding of this discussion, a graphic example from the book is given along with a brief explanation of it, which is presented below. Figure 2.1 shows a cell that has been converted into two spaces b and a with a partition, with a door that allows penetration between these two spaces. As it is known, these two spaces are symmetrical to each other; as b is relative to a. a is also relative to b.

If we call the outer space c and mark it with a circle with a + sign inside it, and show each space with a circle and a line that penetrates the space into another space, the explanatory diagram of this cell will be as shown.

The results obtained from the analysis of these diagrams are such that any change in the way the spaces are arranged will create changes in the overall level of the spatial arrangement, which in turn affects the amount and manner of activities in the spaces. Spatial arrangement, whether in the environment of a building or in the city, imposes some constraints on the people using the space. In addition, the way of understanding the entire artificial

environment (city or building), in addition to other factors, is also related to the way the space is arranged.

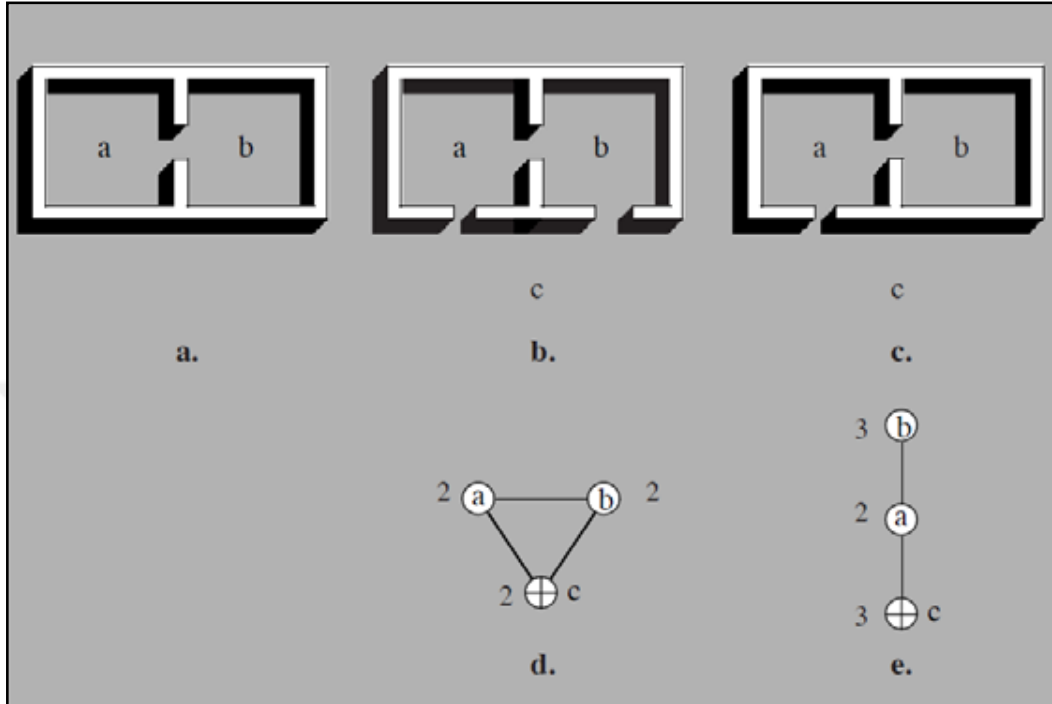


Figure 2.1: Taken From the Book "Space is a Machine", 2007.

2.4 INDICATORS OF SPACE STRUCTURE ANALYSIS USING SPACE SYNTAX METHOD

2.4.1 Connection

Connection or degree, the number of lines that reach a node is called connection.

Each node that has a higher number of connections is connected to more nodes and benefits from the protection of more zeros (Eftadeh, 2015). This index also represents the active nodes. Connecting spaces together is a good indicator to recognize collective spaces and facilitate circulation between spaces (Young, 2015). The amount of connection for each node can be shown as follows:

$$C = K$$

Where K is the number of directly connected nodes (Yazdanfar, 2017).

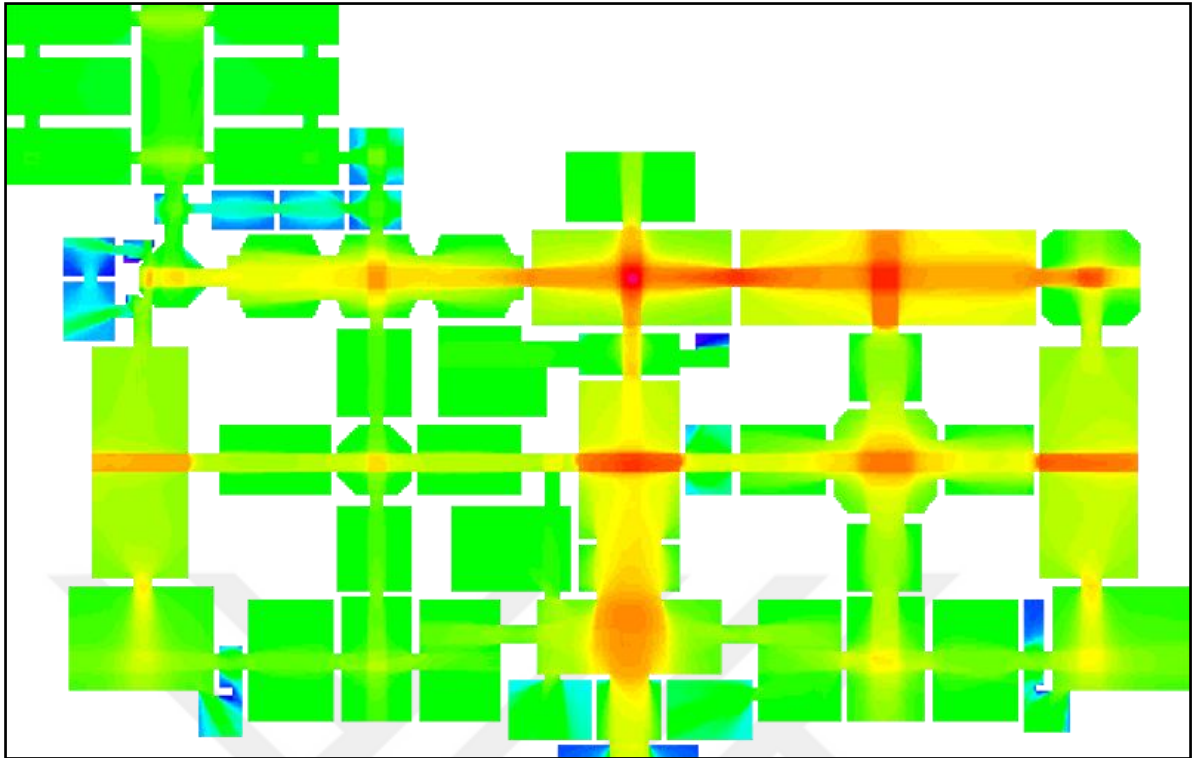


Figure 2.2: Sample Case of Connectivity Analysis

Source: (www.ucl.ac.uk/bartlett/architecture/research/space-syntax/depthmapx)

2.4.2 Integration

The meaning of connection is the degree of integration of a space with other spaces, which is inversely related to the concept of depth; This means that a space or the same node has a high integrity when the rest of the nodes are located in a small depth compared to it, and this connection causes the user to change direction to go from one space to another. The correlation index has a direct and linear relationship with the connection index. That is, the more connections a space has and the more nodes it connects with, the higher the degree of connectivity (Heydari, Ghasemian, Isa, 2016).

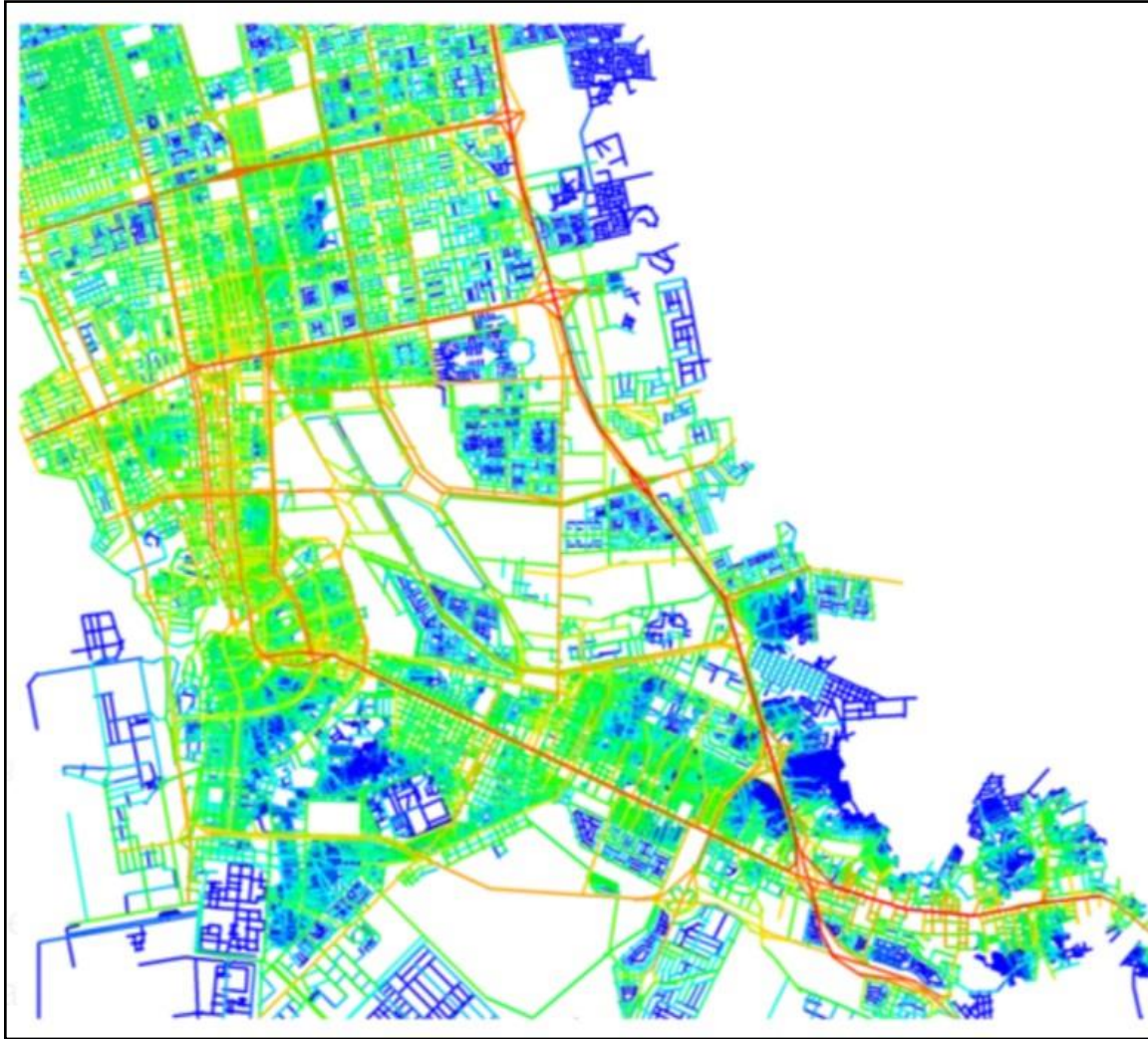


Figure 2.3: Sample Case of Integration Analysis-Global Choice Pattern.

Source: (<https://medium.com/data-mining-the-city-2022/space-syntax-urban-network-spatial-relations-7679de91beb>)

Dense Texture of Organic and Indoor Sidewalk

This type of alley is called Sabat. Features of Yazd texture is the protection of all passages, yards and buildings against atmospheric factors and especially wind. Also, wind and sun are used in the best possible way with methods such as windbreaks. The texture in these spaces is compact and connected, and the alleys are narrow and relatively long and broken in the direction of a line, the alleys are sometimes roofed or have a sabbatical. Narrow alleys with high walls create shadows along the alleys and protect passers-by from the sun. Due to the winding nature of these alleys, the wind breaks in them and pedestrians are less bothered by the monsoon winds (Sahebzadeh, Heidari, Kamelnia, Baghbani, 2017) (Figure 2.3).

2.4.3 Depth

This index is divided into two parts in the space arrangement method, the first part means the metric depth or the distance between two nodes. The second part means the number of nodes that must be traversed to go from node one to node two. It should be noted that the parameter of depth index and integrity have an inverse relationship with each other (Memarian, 2006).

2.4.4 Accessibility

Visual access and physical access are checked in two parts. Visual access is calculated with the name of Isovist and physical access is calculated as metric depth (Haidari, 2016). Isovist can actually be called the user's cone of vision in relation to the surrounding space at a desired point (Benedikt, 1979).

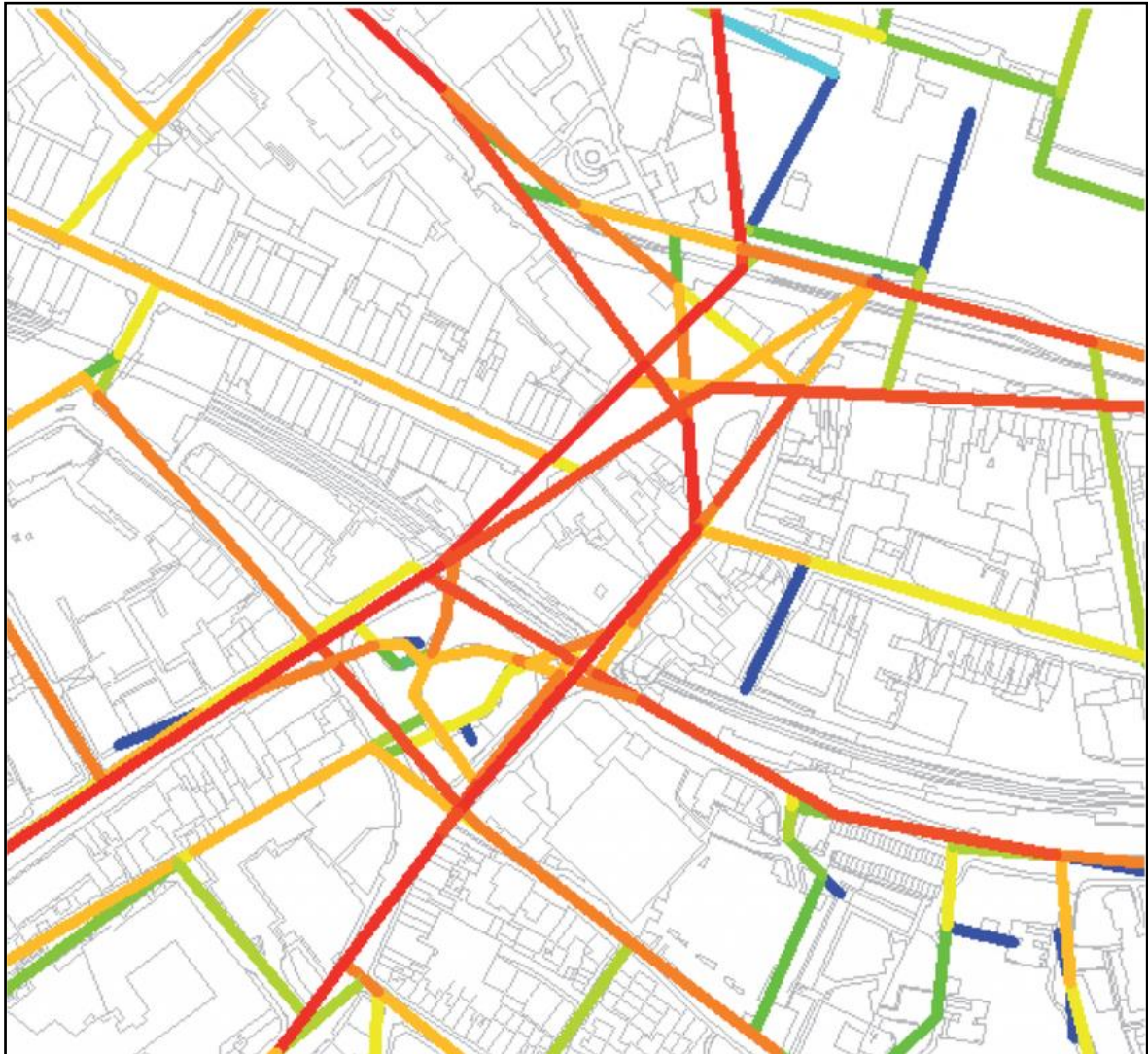


Figure 2.4: Example of Spatial Accessibility Models Created Using Space Syntax.
(Image taken from Woolwich Squares Space Syntax project, spacesyntax.com)

2.4.5 Natural Movement

Urban spaces play an important role in meeting the need for social interactions of humans, an important part of which is fulfilled by face-to-face interactions. The lack of direct and face-to-face communication between people has many consequences on the mental health of people (Abbaszadegan, 2012). It can even be said that the social function of the urban plan is determined to some extent from the pattern of their daily movement (Legeby, 2013). As mentioned, the manifestation of this communication and interaction is urban and architectural spaces, and it also includes part of the behavior of users in the environment.

The theory of space arrangement considers the natural movement of people in space, which is actually traffic to get from the origin to the destination, directly related to the structure of the space arrangement. It also states that factors such as land use distribution and spatial attraction have less effect on the natural movement of users (Hillier, 1993). The logic of natural movement is such that the spatial composition affects the movement and spatial attractions, while it is not affected by them. In other words, people pass through a space under the influence of spatial structure more, as a result, spaces are created that are proportional to the population density in those areas, and this in itself causes an increase in transit density (Abbaszadegan, 2013).

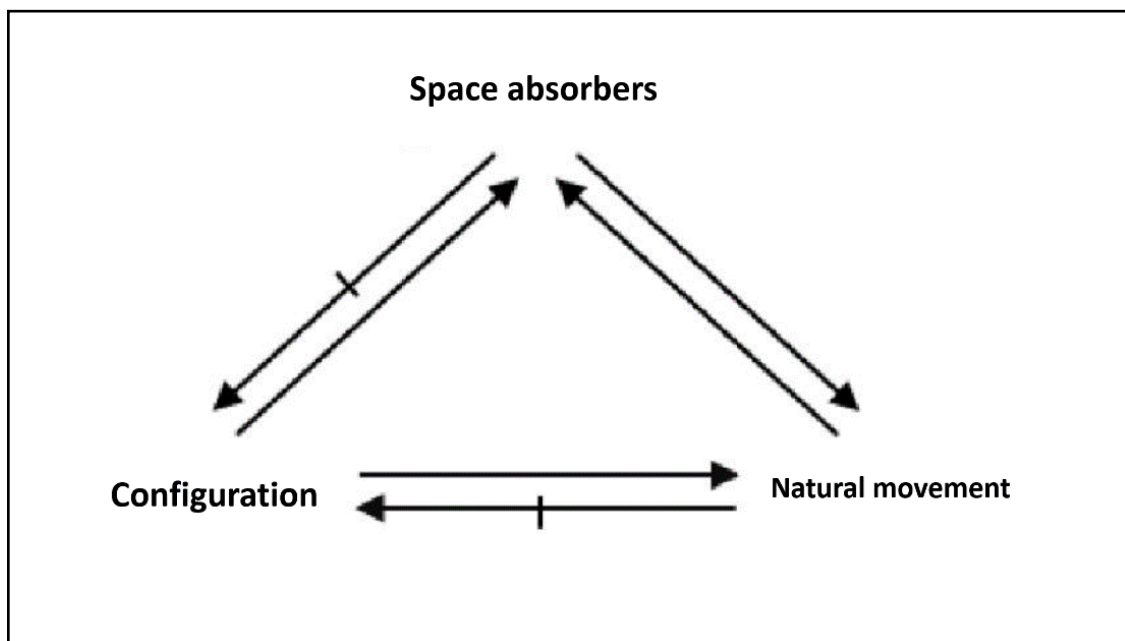


Figure 2.5: The Logic of The Theory of Natural movement, Source: Hillier, 1993.

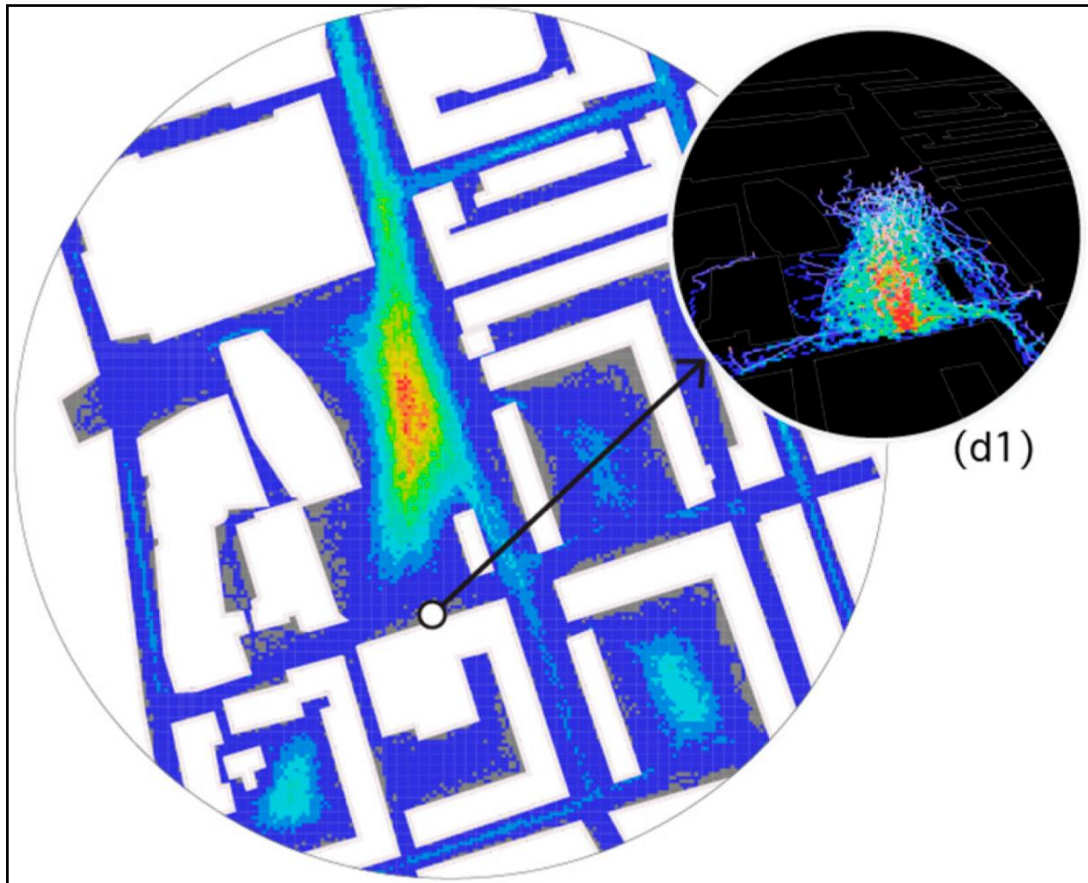


Figure 2.6: Agent Movement Based Model.
 Source: (<https://www.mdpi.com/2071-1050/13/6/3394>)

2.5 SAMPLE: COLLEGE OF ARCHITECTURAL ENGINEERING AND DIGITAL DESIGN

2.5.1 Selection of a Case Study and Its Description

For the case study to continue, the building of the College of Architectural Engineering and Digital Design (CADD) at Dar Al Uloom University in the Kingdom of Saudi Arabia has been chosen. The decision is made based on two primary factors:

- a. Its simple configuration, "linear pattern," and rectilinear forms, which predominate in college building circulation types. Because it permits the straightest views with good visual access, clear cognitive mapping, and high levels of readability, the linear plan is the most prevalent circulation style in higher education buildings. Strong directionality and a perspective impact provided by linear passageways direct and draw users of the space to the

end of the hallway, enhancing the aesthetic appeal of the courtyard area. The CADD floor design is shown in Figure 2.7 together with utilization, transition spaces, and glazing barriers.

b. The CADD ward has adopted a contemporary design trend since 2000 with the rising use of glass in educational facilities in order to be pertinent to the research's focus. Traditional walls have been removed and the visual and physical barriers separating inside and outside have been decreased thanks to new materials like glass (Figure 2.8).

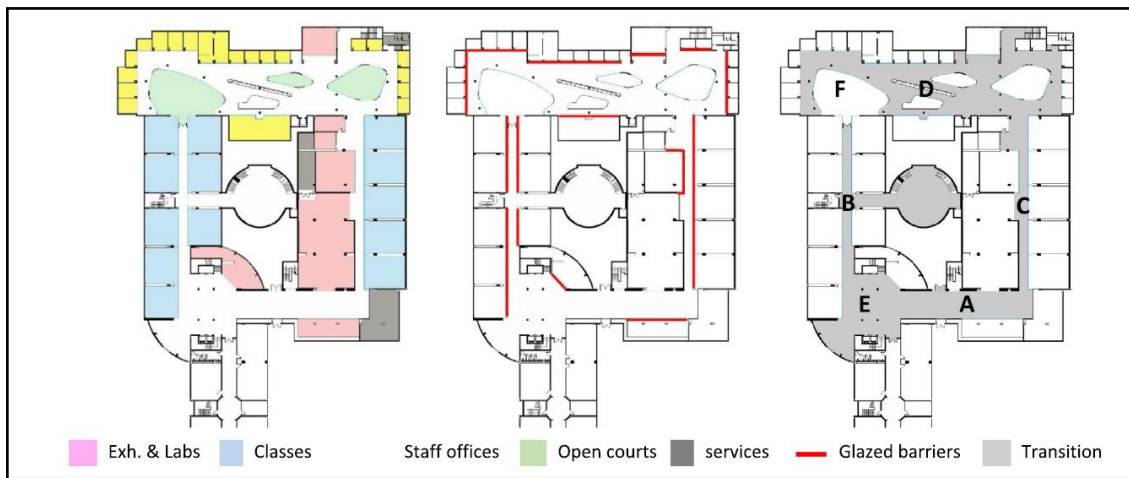


Figure 2.7: Plans for the College of Architectural Engineering & Digital Design - DAU, KSA, shown in an Illustrative Manner.



Figure 2.8: Interior Photos for CADD Transition Spaces Display Glazed Partitions on Both Sides of the B and C Spaces that Serve as a Physical and Acoustic Barrier and Maintain Visual Consistency for Classes.

2.5.2 Analysis of Glazing's Effects on Function Using VGA (Figure 2.9)

- a. Visual integration showed just a slight variation between the two scenarios because all visual destination areas remained the same, with a slight rise in values in the case of Z because of the wide visual ranges brought on by glass.
- b. Space D, which consists of offices and open spaces, maintains its current layout throughout.

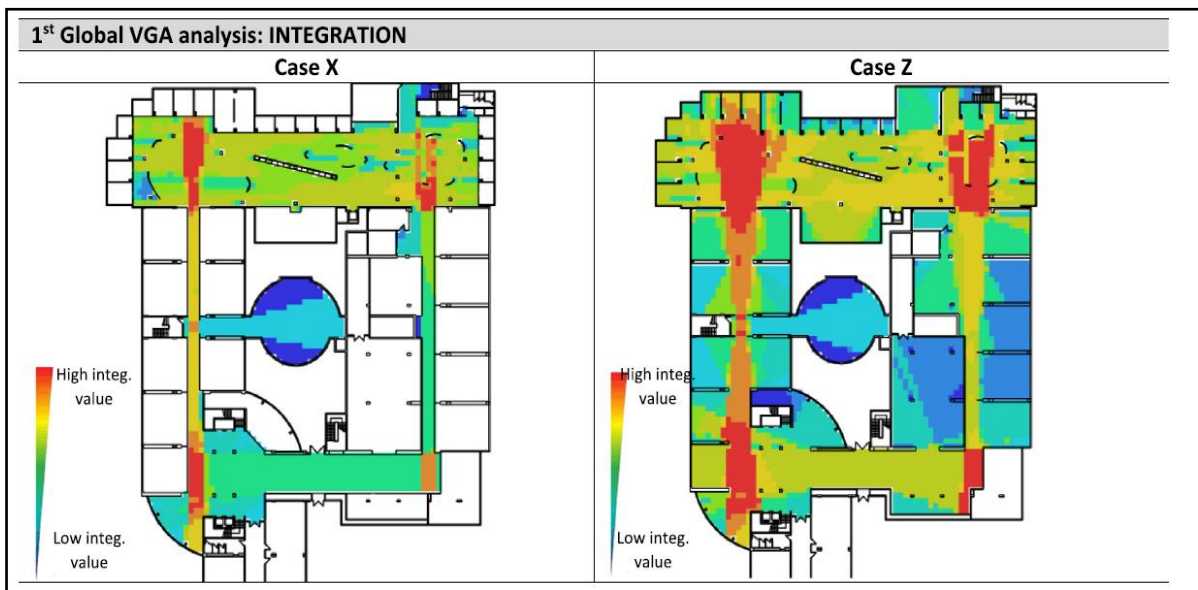


Figure 2.9: Analysis of the Visual Integration in Cases X and Z in Comparison.

2.5.3 Analysis of Glazing's Effects on Function Using VGA (Figure 2.10)

- a. Evidently, the installation of the glazing raised the values for visual accessibility, particularly in Corridors B and C.
- b. The Corridor B's succession of glazed classrooms contributed to the corridor's increased visual accessibility and created a visual link between Spaces E and F along the corridor. This function, which links the entrance with the areas of senior managerial employees, may be in line with the high values of integration for such spaces.
- c. Increased visual accessibility in Space D might be beneficial for encouraging interactive activities there.

e. For the solitude and tranquility necessary in these places, the visual accessibility in areas adjacent to staff offices continues to show low values.

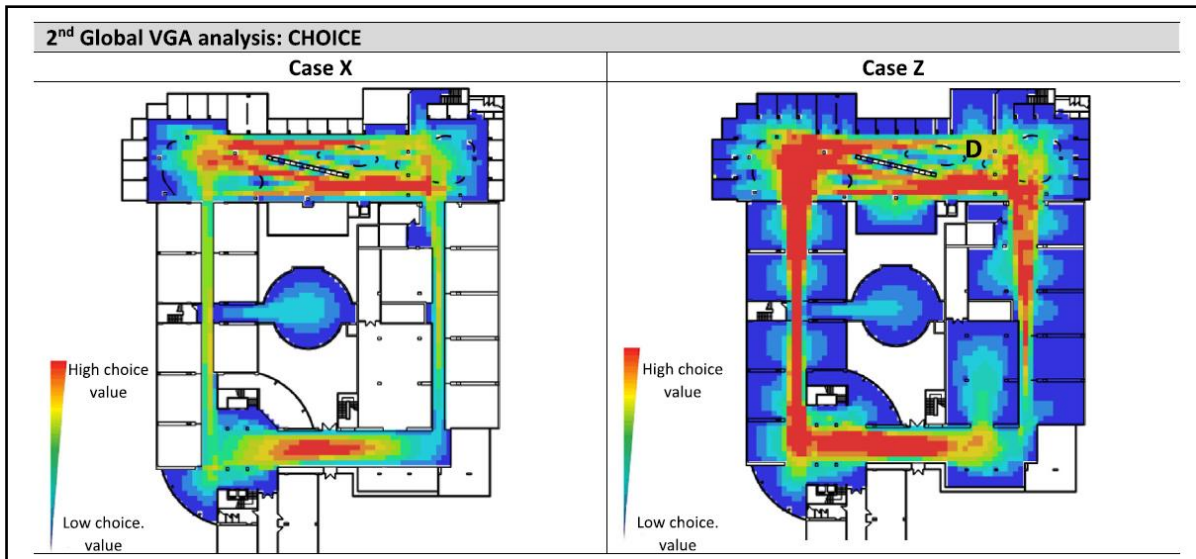


Figure 2.10: Analysis of the Visual Choice in Cases X and Z in Comparison.

2.5.4 Axial Analysis is Discussed (Figure 2.11)

- a. When comparing the results of the axial integration analysis in the two examples, it is clear that more routes are now slightly more significant in case Y, and that case Y's average value of axial integration is higher than case X's.
- b. The most crucial and integrated paths on the map are shown in red following axial integration analysis. These highly integrated pathways, meanwhile, are compatible with the attached functions that constitute significant destinations.
- c. The approach with the highest integration in case X and any associated functions that are not essential or crucial are inconvenient. The highest path is altered in instance Y, though.

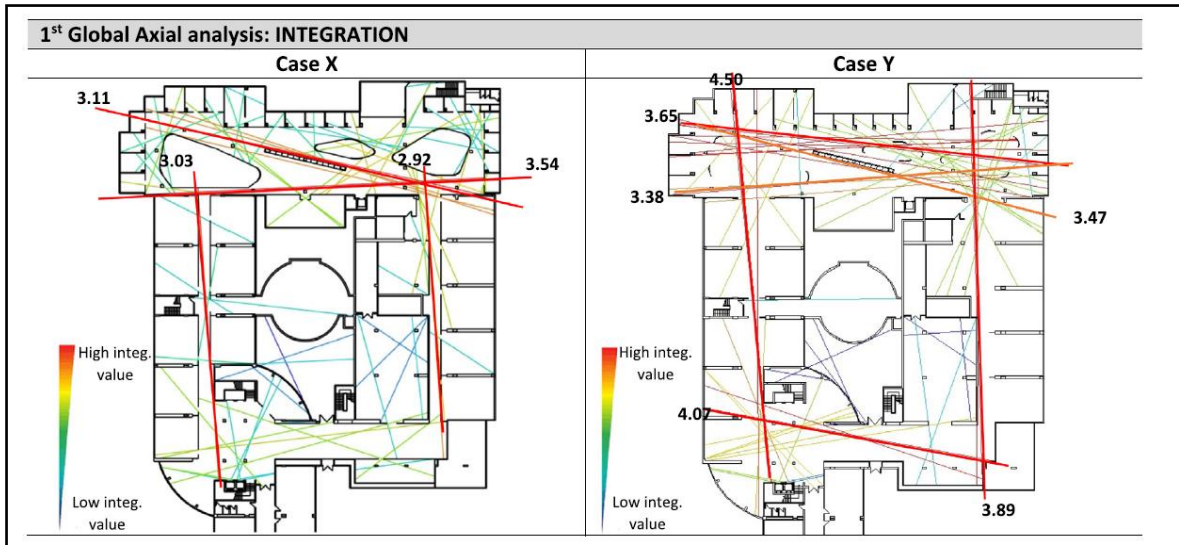


Figure 2.11: Integration and Selection Measurements are Used in the Axial Analysis for Case X.

2.5.5 Axial Analysis is Discussed (Figure 2.12)

- a. When axial choice analysis results from the two cases are compared. It is clear that the most accessible paths forming the main transition space for the entire configuration are nearly identical and support the necessary levels of privacy for staff offices. Even though the average value of the axial choice analysis result for case Y is lower than it is for case X.
- b. The route with the highest choice/accessibility value is related to customers' actual experiences since it links Space F's main entrance with this crucial area via elevators and stairs.

Notably, high integration levels result in highly accessible pathways being nearly identical.

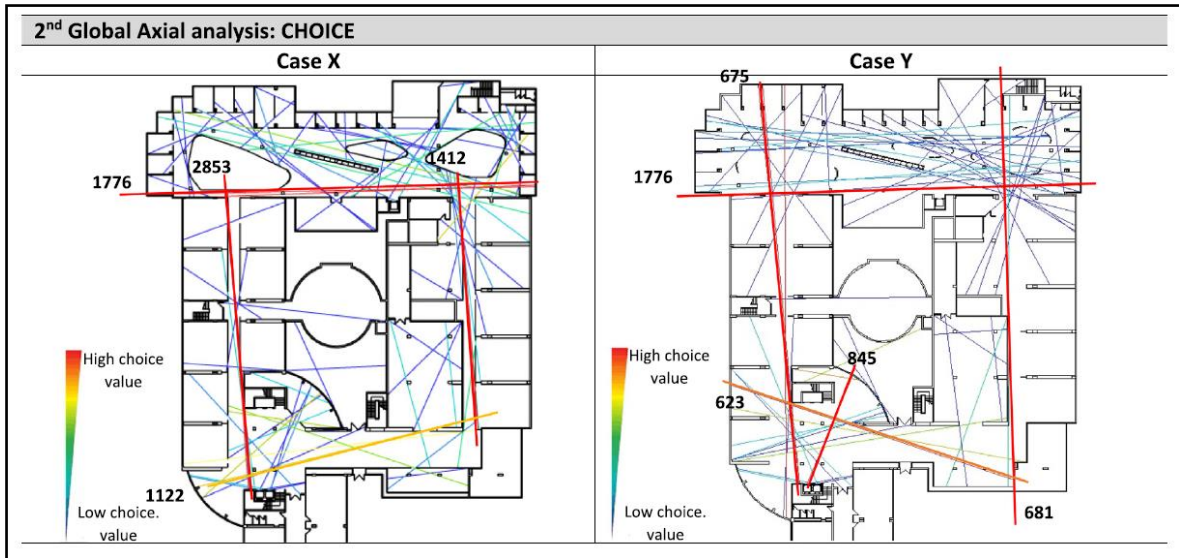


Figure 2.12: Integration and Selection Measurements are Used in the Axial Analysis for Case Y.

2.6 SAMPLE: INTRODUCTION OF CHONGQING IRON & STEEL TRANSFORMATION PLAN

Hanyang Iron Works, established on September 1, 1890, by Zhang Zhidong, Huguang Governor of the Qing Dynasty, was the forerunner of Chongqing Iron & Steel. In March 1938, it was transferred to Dadukou, Chongqing. It was reorganized in June 1995 to become Chongqing Iron & Steel Group Co. Ltd., which is today Chongqing's biggest state-owned company. The economic growth of Dadukou has been greatly aided by Chongqing Iron and Steel. However, it has also caused significant environmental pollution. The factory was relocated to Changshou in order to achieve industrial structure adjustment and sustainable urban development. Figure 2.13 shows a schematic diagram of how the former Chongqing Iron & Steel site will be turned into the Chongqing Industrial Museum and Creative Industry Park. The incorporation of two significant axes that correspond to the viewpoint axes of prominent industrial artifacts like the gas tank and chimneys is part of the area's overall layout. The atmosphere of culture and commerce can be produced through the use of two mutually perpendicular and distinctive axes. The large-span steel factory, the fifty thousand-cubic-foot tank, the plant from the time of the Republic of China, the main electrical room, and the chimney are the major industrial artifacts that the entire rehabilitation project has reserved. Buildings that are part of the industrial cultural environment include the canteen, restrooms, and waiting areas for the workers. The project includes a number of open spaces,

such as rail square, chairman trails, Heritage Park, the new stadium and plant exhibition district, the old factory courtyard garden, and others. These spaces can accommodate a variety of activities, including performances, the release of industrial products, and the sale of consumer goods and works of art. Chongqing Industrial Museum and Creative Industry Park is one of them, and it consists of the plant's original manufacturing structures as well as the recently constructed "Rust Stripes" next to chairman paths. The original industrial building is still present on the first three levels of the recently constructed "Rust Stripes." The longest factory space and the "Rust Stripes" form an interesting spatial interaction. The core project of the entire renovation project is the old factory buildings and surrounding area, which is at the center of the entire reconstruction project (Wang, Li, Zhang, Li and Xu, 2017).



Figure 2.13: The Transformation Plan's Schematic Diagram.
Source: (Wang, Li, Zhang, Li and Xu, 2017).

2.6.1 Local Integration Analysis

The term "three steps" here refers to the topological distance, while "local integration" investigates the system's proximity to all other convex spaces below that distance. The findings demonstrated that the red portion of (Figure 2.14), which reaches 3.75, represents the amount of trunk road integration that is highest in the office area. The office's two sides are connected by a road that is intimately connected to its surroundings. The second are the

two axes routes close to the museum and industrial park; their integrations are 2.75 and 2.16, respectively. The museum, the creative industry park area, and the street commerce buildings are connected by the road to the left of the museum in Figure 3.10 so that they can cooperate to draw attention and share consumer traffic. In comparison, the museum area's local integration score is only 1.73, showing a lack of effective interaction with the surrounding neighborhood. (Wang, Li, Zhang, Li and Xu, 2017).

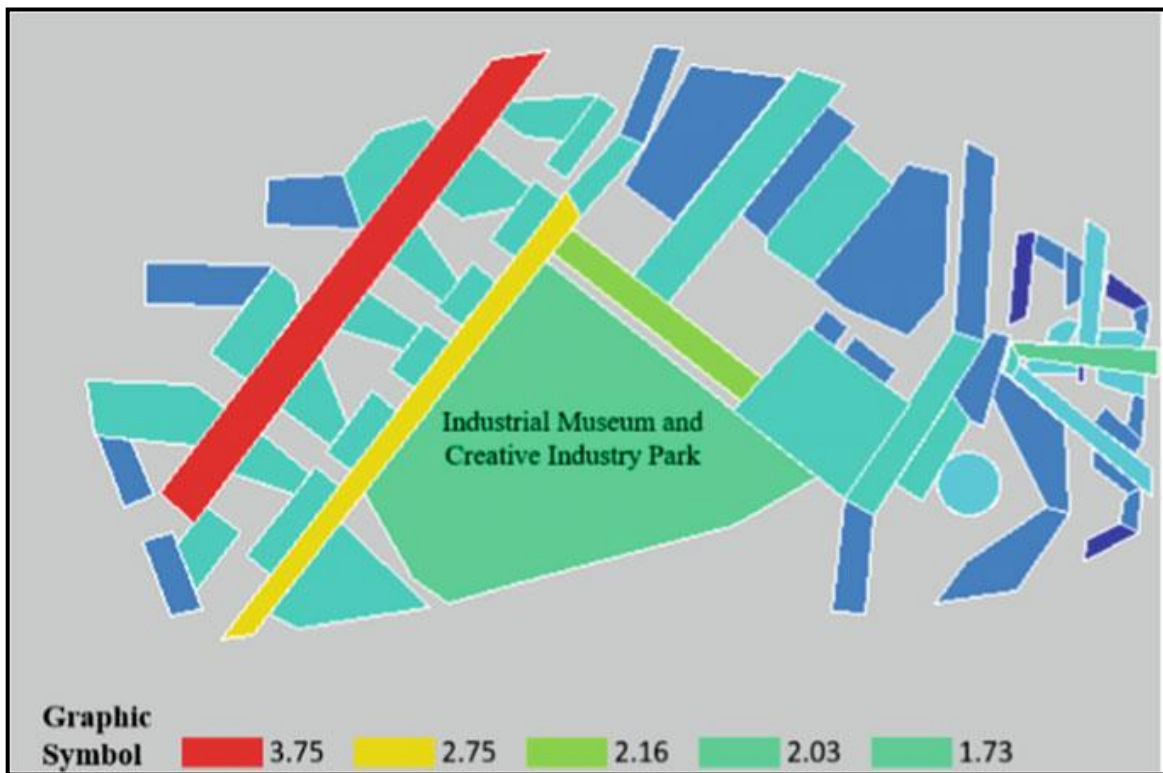


Figure 2.14: Analyses of Local Integration in Convex Space.
Source: (Wang, Li, Zhang, Li and Xu, 2017).

2.6.2 Connectivity Analysis

By examining the connectivity between the museum and the creative industrial park region, it can be seen that there are only three connections between the two, as shown in (Figure 2.15), indicating that the museum has few connections to its surroundings and that its permeability is unsatisfactory. This has to some extent reduced the region's engagement with the surroundings. While the connectedness values of the adjacent street and road are 5 and 10, this once again demonstrates that the axis road's space permeability is better, and the axis

road has been crucial for the linkage of the complete space system (Wang, Li, Zhang, Li and Xu, 2017).

2.6.3 Depth Analysis

For assessing spatial accessibility, depth is crucial. Lower depth values indicate a shorter topological distance needed to reach this area, making it substantially more accessible. The entire topological distance needed to go between every space in the system and a given space is known as the global depth. It describes how easy it is to go to a particular space from different points within the space system (Wang, Li, Zhang, Li and Xu, 2017).

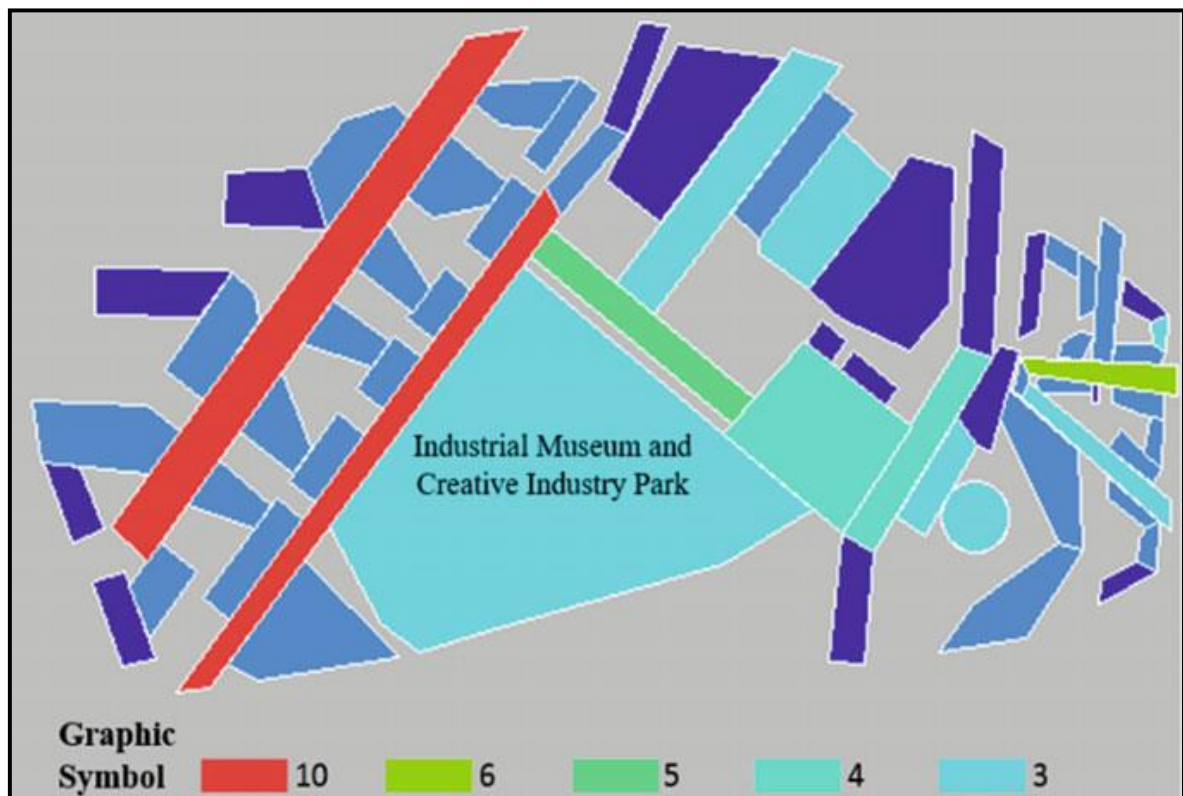


Figure 2.15: Convex Space Connectivity Analysis.
Source: (Wang, Li, Zhang, Li and Xu, 2017).

According to Figure 2.16, the museum and creative industrial park has a global depth value of 144, while the two main roads that are next to it have global depth values of 121 and 129, respectively. The portion's overall depth value falls inside the middle of the total space system. The blue region of (Figure 2.16) contains the lowest global depth value, which ranges from 40 to 60. This demonstrates that this part is more accessible and that less spaces

are needed to get to it. Additionally, this area was designed with commerce in mind in order to make it easier for customers to access and explore, which will have positive effects on the industry (Wang, Li, Zhang, Li and Xu, 2017).

2.6.4 Space Attribute Analysis of Outdoor Plazas

Two outdoor plazas have connection values of 2 and 3, local integration values of 1.37 and 1.49, and global depth values of 161 and 166, respectively. Their accessibility, permeability, and centrality are generally inadequate as public spaces, and their many spatial characteristics are inferior to other public spaces, making it challenging to fulfill its public space functions (Wang, Li, Zhang, Li and Xu, 2017).

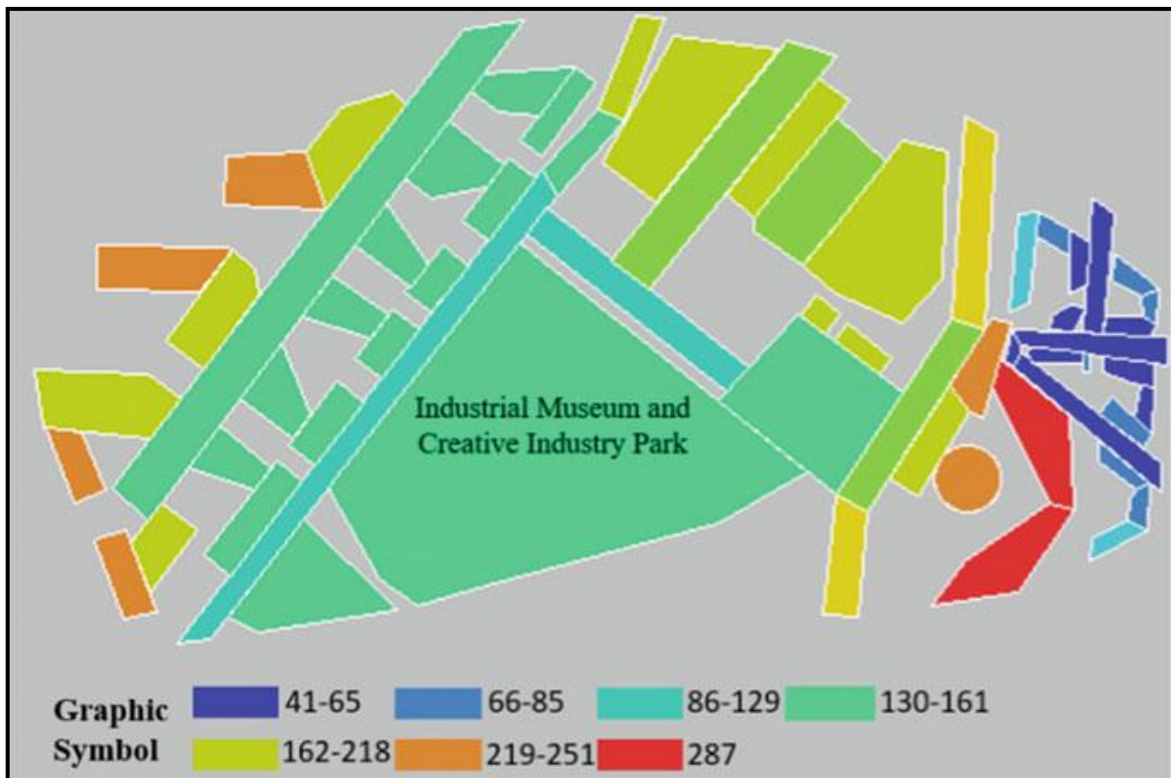


Figure 2.16: Convex Space Depth Analysis.
Source: (Wang, Li, Zhang, Li and Xu, 2017).

Outdoor plazas have a comparatively peripheral position and have only sporadic connections to the rest of the space system. It is challenging for the two outdoor plazas to accommodate the audience that wants to take a break because of their inadequate centrality. Additionally, improving the internal linkages across space systems is impossible due to the absence of connectivity with neighboring spaces (Wang, Li, Zhang, Li and Xu, 2017).

As a result of Chongqing Iron & Steel's metamorphosis, the entire office area has good spatial agglomeration and permeability, and the commercial portion's A side has good spatial accessibility. However, the division of the two business zones, A and B, makes it impossible for the two to work together. Additionally, the A commerce part is located in a remote area of the entire region and has poor accessibility and concentration, so it's possible that the operation's outcome won't be encouraging. The two main highways, which are in the center of Chongqing Iron & Steel, have the most balanced performance in terms of spatial concentricity, permeability, and accessibility. They are located next to the Industrial Museum and Creative Industry Park. Due of limitations in location and access to roads, the two outdoor plazas cannot function as useful public areas. Despite being in the center of the entire region, the museum and creative industry park's accessibility, permeability, and concentration are far from being at the same level as the core location, and Chongqing Iron and Steel's spatial function still needs to be addressed (Wang, Li, Zhang, Li and Xu, 2017).

2.7 SAMPLE: DESIGN PRACTICE IN BUILDING CONTEXT: TATE BRITAIN

Tate Britain's administrative division has opted to add new display spaces to the museum to improve the arrangement. The plan was to expand the current gallery by designing a new wing with a sculpture courtyard. Tate Britain has hired Space Syntax to support Tate Britain and its designers Allies and Morrison. Both through shedding light on the social culture within the museum, which was communicated through the spatial configuration itself, and by assisting architects Allies and Morrison in evaluating their three options, Space Syntax Laboratory has contributed to the design process (Figure 2.17) (Figure 2.18). Space Syntax Laboratory recorded pedestrian activity in approximately 300 places throughout the course of the research at various hours of the day, on various days of the week, and throughout various times of the year. 100 people's itineraries were tracked during the project for the first ten minutes of their visits. According to the survey's findings (Hillier, 2004, Hillier and Tzortzi, 2006), some areas of the museum receive much more visitors than others (Figure 2.17) (Figure 2.18). From the main entrance, traffic tends to flow along the center axis and pick up significantly on the left side of the structure. This characteristic was confirmed by visibility graph analysis by recreating the reported visitor movement (Dursun, 2007).

2.7.1 Comparative Analyses

After it was established how the current spatial arrangement functions spatially, comparative studies of alternatives in terms of their potential impacts on the museum were conducted. One of the initial ideas was to build a new gallery wing with an entrance through the Clore Gallery for the permanent collection. At the back of this wing, a sculpture court was intended to be an outdoor space. The second idea attached some of the new gallery spaces in a linear fashion to the north side of the structure, while the remaining ones were planned as a separate wing at the back of the building, forming an open court in the middle. The third one added a new north wing that would house temporary exhibits, while the area now housing temporary displays was created to house the permanent collection. In this design, a sculpture court with access to a new café and bookstore was created between the Clore Gallery and the new gallery wing (Dursun, 2007).

2.7.2 Visibility Graph Analyses

According to visibility graph assessments of the plans, the third concept, which makes the new temporary exhibition space well integrated and well related to the core of the building, offers the best understandable arrangement (Space Syntax, 2002). This idea also has a positive effect on the existing building by giving the plan a strong overall structure by introducing a new link between the left side of the Gallery, the Clore Gallery, and the new spaces, as well as by creating a new route to the Clore Gallery (Dursun, 2007).

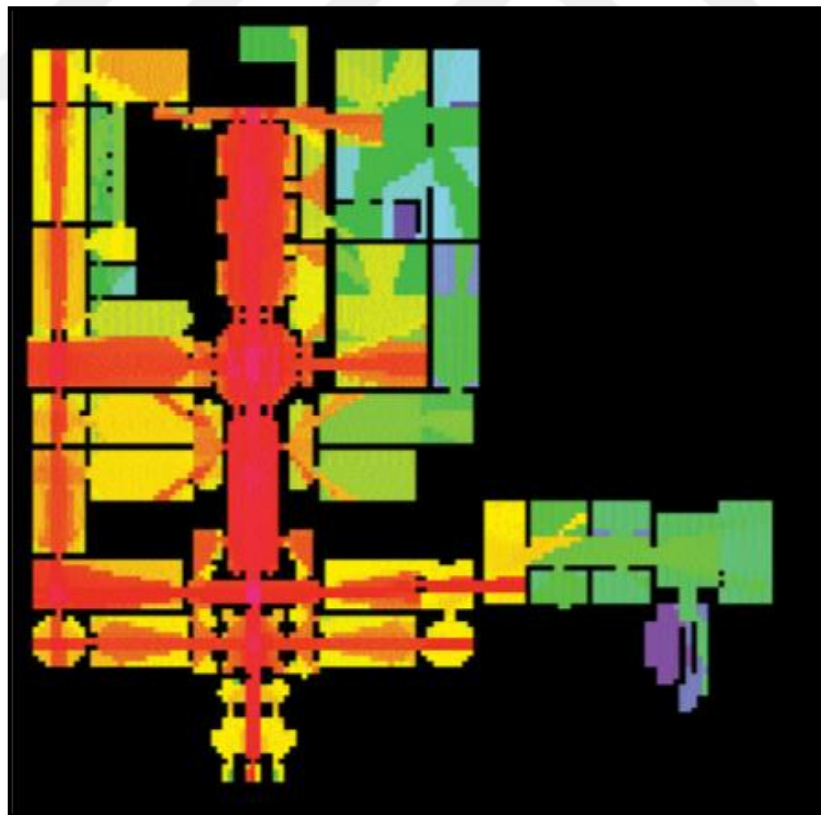
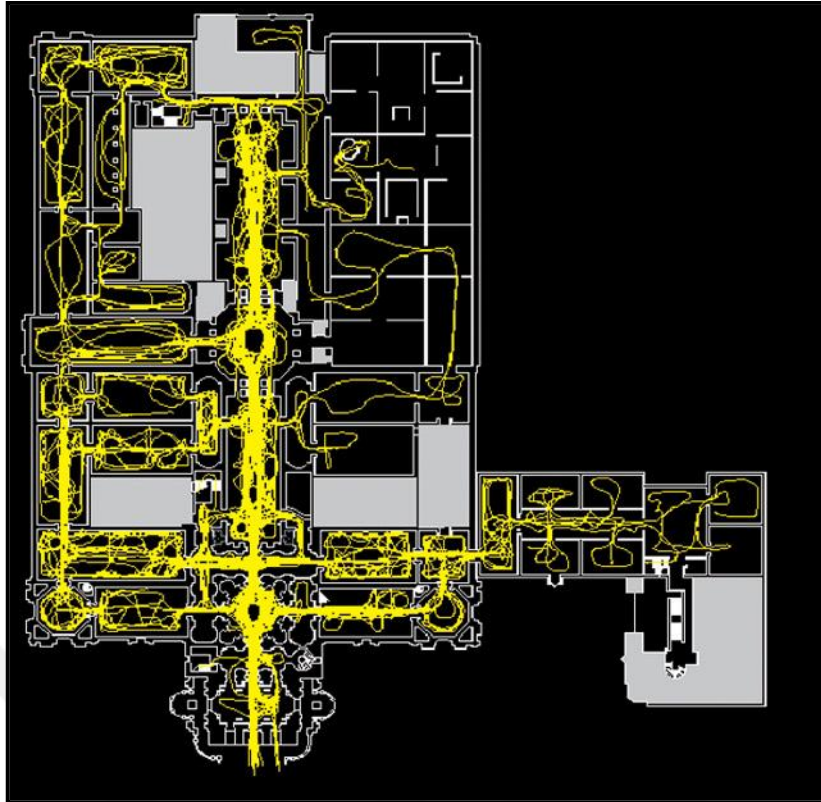


Figure 2.17: Movement Traces and Vga Analyses in Existing Museum.
Source: (Dursun, 2007).

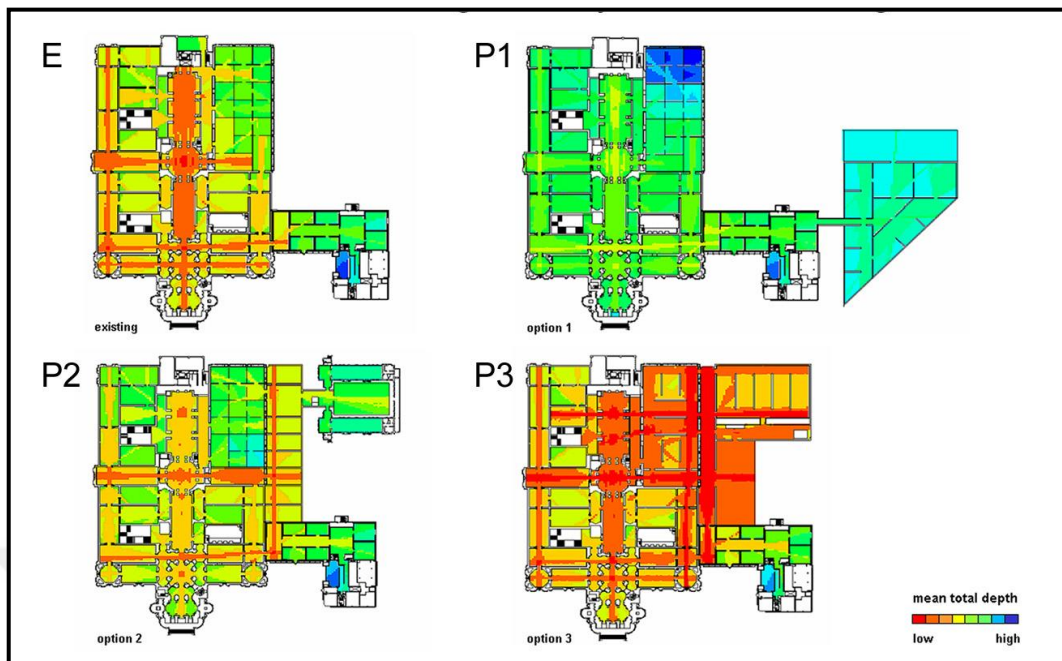


Figure 2.18: Testing Three Design Proposals.
Source: (Dursun, 2007).

By examining the current spatial layout, this exploratory work on Tate Britain has both helped designers learn about the social codes in the museum and assisted them in prototyping their ideas. Designers have the opportunity to assess and refine their concepts in the light of scientific facts by simulating the potential consequences of design decisions on the current plan arrangement (Dursun, 2007).

3. INDUSTRIAL BUILDINGS

What precisely is an industrial building, first of all? One of the four primary categories of commercial real estate used for business purposes, as we've already mentioned, is an industrial building. Simply described, industrial buildings are big establishments like factories or warehouses that are primarily used for producing or storing goods, services, or raw materials for commercial use (<https://www.branco.com/deep-dive-into-industrial-building-construction/>).



Figure 3.1: Industrial Building.

Source: (<https://cushwakewr.com/property/industrial-building-for-lease-in-cambridge-105-boxwood-drive/>)

3.1 DEVELOPMENT FACTORS OF INDUSTRIAL BUILDINGS

Four important events, including Renaissance, religious reformism, enlightenment and industrial revolution, created the basic elements of modernism or modernity in Europe. One of the pillars of modernity is the industrial revolution, which extends from the second half of the 18th century to the first half of the 19th century. The emergence of modern methods

and tools and the growth of technology provide the mass production of goods and cause the transition from agricultural and commercial society to modern industrial society. During this period, a huge transformation occurred in the development of industries and engineering knowledge. Architects, who until then relied more on traditional and common construction methods, gradually learned the available scientific and technical techniques in order to meet their architectural demands. At the end of the 17th century, the changes in the world of economy and industry were such that a specific field for professions distinct from architecture emerged. The modern profession of "engineer" with its numerous branches and sub-branches has taken over many traditional areas of architecture and its scientific effort. The industrial revolution brought huge changes in all areas of human life, such as the development of consumerism, industrialization, and the rapid growth of urbanization (Ziyari, 2003). The industrial revolution brought huge changes in all areas of human life, such as the development of consumerism, industrialization and the rapid growth of urbanization.

3.2 DEFINITION OF INDUSTRIAL BUILDINGS

An industrial building is a space surrounded by walls, ceilings and floors, in this area, openings, openings and other necessary arrangements for the passage of pipes, cables, channels, air conditioning systems, as well as suitable doors and windows. It has been provided with industrial operation (installation of equipment and machines) (Goodfellow, 2001). These buildings house manufacturing industries and infrastructure, and vital production and service activities of society are carried out in them. Power plants, factories, refineries, large industrial warehouses, and other industrial complexes include buildings with the mentioned conditions. According to the definition of Siemens, a factory or industrial complex is a set of machines and equipment that work together to produce the final product. An industrial complex does not only include machines, but also infrastructure such as power, ventilation, and waste disposal (Siemens, 2014). The conditions of these buildings are such that for reasons such as creating mercy for the citizens, making a lot of noise, producing all kinds of environmental pollutants (many of which are chemicals) and many other cases, it is necessary as far as possible. They are being built on the outskirts of cities and far from social and residential places in urban and rural areas (Arkan Paoish Consulting Engineers, 2005).

3.3 INDUSTRIAL ARCHITECTURE'S KEY ELEMENTS

Industrial architecture can take many different shapes, although some characteristics are common:

- a. Combining design and functionality
- b. Open, spacious floor layouts
- c. Soaring ceilings
- d. Using raw, unfinished elements like metal, masonry, and concrete
- e. The façade of the building is unadorned.
- f. Coatings that are worn and distressed due to extensive use over time
- g. Exposed ductwork, pipe, and masonry that would typically be covered up during residential building
- h. Large windows with metal grids (<https://www.thespruce.com/what-is-industrial-architecture-4796580>).

3.4 TYPES OF INDUSTRIAL BUILDINGS

What precisely do industrial facilities do? One of the four main categories of commercial real estate utilized for business purposes is an industrial building. Industrial facilities are huge buildings like factories or other locations where raw materials, finished goods, or services are largely produced or stored for commercial purposes (<https://www.ppvvs.uk/news/what-is-an-industrial-building>).

3.4.1 Warehouse

These common single-story warehouses are used for the storage and transportation of commodities and range in size from 5,000 to hundreds of thousands of square feet. Because of the essential racking and storage systems hidden beneath its roof, ceilings are typically at least 60 feet high. Loading docks, large truck doors, and parking spaces for distribution-related semi-trailers are a few other crucial components of an industrial facility (<https://www.ppvvs.uk/news/what-is-an-industrial-building>).



Figure 3.2: High-loading dock doors at the Getagadget Warehouse.

Source: (<https://aquilacommercial.com/learning-center/types-of-industrial-buildings-defined-warehouse-flex-distribution-etc/>)

3.4.2 Manufacturing

Manufacturing buildings, sometimes referred to as heavy industrial buildings, are sizable establishments that store machinery that is expensive to buy and maintain. A few examples of this type of industry are the oil, mining, and shipbuilding sectors. The huge machinery inside these structures is powered by a three-phase electric power source. They often have massive ductwork paired with high-capacity ventilation and exhaust systems to expel dangerous chemicals and vapours from the plant and provide clean air. Finally, they usually include crucial components like floor drains and storage tanks as well as pressurized air or water lines so that the technology can function properly (<https://www.ppvs.uk/news/what-is-an-industrial-building>).



Figure 3.3: Manufacturing Buildings.
Source: (<https://www.sprung.com/structures/industrial-buildings/manufacturing/>)

3.4.3 Light Manufacturing

Light manufacturing requires less capital than the massive industrial structures mentioned above. Textiles, furniture, and home electronics are a few examples of light industries. Light manufacturing structures often need less space, electricity, and resources to function (<https://www.branco.com/deep-dive-into-industrial-building-construction/>).

3.4.4 Refrigeration

Distribution hubs for food products like meat, fruit, and dairy are refrigeration and cold storage facilities. These structures have facilities for freezing and cooling that keep products at the proper temperature until they are sent. Other important characteristics are insulated overhead doors that keep supplies frozen and docks with specific seals to keep products cold (<https://www.ppv.s.uk/news/what-is-an-industrial-building>).



Figure 3.4: Refrigerated Warehouse.

Source: (<https://www.strand.com/services/buildings-and-facilities/refrigeration/>)

3.4.5 Telecom and Data Hosting Centers

In order to manage a company's network and data, large computer servers and related equipment are kept in these specialized facilities, which are typically around 100,000 square feet in size. These buildings, also known as switching, cyber, or online hosting facilities, include a redundant power supply (two or more units) to ensure that technology can continue to run in the case of a potential loss from one source. These buildings also have elaborate security systems, specialized HVAC units that can effectively cool the machinery, and reinforced floors to sustain the tremendous weight of the equipment (<https://www.branco.com/deep-dive-into-industrial-building-construction/>).



Figure 3.5: Vantage Data Centers Buys Hyper scale Data Center Business in Montreal.

Source: (<https://hostingjournalist.com/vantage-data-centers-buys-hyperscale-data-center-business-in-montreal/>)

3.4.6 Flex

A "flex building" houses several different business operations connected to the production process under one roof. This provides a "flexible" solution to fit a business's particular

requirements. For instance, a small warehouse, research and development facility, or even a showroom could be combined with office space. Flex buildings frequently have lower ceilings of 14 to 24 feet and more office space than a traditional warehouse (<https://www.branco.com/deep-dive-into-industrial-building-construction/>).



Figure 3.6: Location of Shushtar city in Iran.

(Source: <https://www.semanticscholar.org/paper/New-Towns-Promises-Towards-Sustainable-Urban-Form-Shirazi/cfc1904f60f21efd8da27b7d20c75a395522e010>)

3.4.7 Showroom

An office, warehouse, or both that are located on a bigger site and have a public display space are called showrooms. A car dealership is a good illustration. A showroom's structure and design are similar to those of a flexible building. However, typically around half of the building is devoted to the retail space in a showroom in order to exhibit and sell things on-site (<https://www.ppvvs.uk/news/what-is-an-industrial-building>).



Figure 3.7: Showroom building on Behance.

Source: (<https://www.behance.net/gallery/38253653/Showroom-Building>)

3.4.8 Research and Development

A research and development center is another type of flexible facility that is typical of the biotechnology and technology sectors. In order to create and improve products, research and development centers sometimes combine offices, labs, and even manufacturing spaces on a

campus-like location. Due to its electrical testing labs, research & development buildings may demand more power than a normal flex facility (<https://www.branco.com/deep-dive-into-industrial-building-construction/>).



Figure 3.8: Research and Development Building.

Source: (<https://www.architectmagazine.com/project-gallery/research-and-development-laboratory-building-5583>)

3.4.9 Biotechnology

Another category of flexible buildings are biotechnology facilities, which are mostly labs for testing and analyzing pharmaceuticals, chemicals, and other biological processes. Wet labs, or experimental rooms that involve the handling of many kinds of chemicals and liquids, are what biotechnology buildings are, according to the term (versus dry labs that focus on simulations). Buildings used for biotechnology require specific planning to prevent contamination and spills because to the potential risks. Examples include temperature controls, specific piped utilities, and direct ventilation (<https://www.branco.com/deep-dive-into-industrial-building-construction/>).

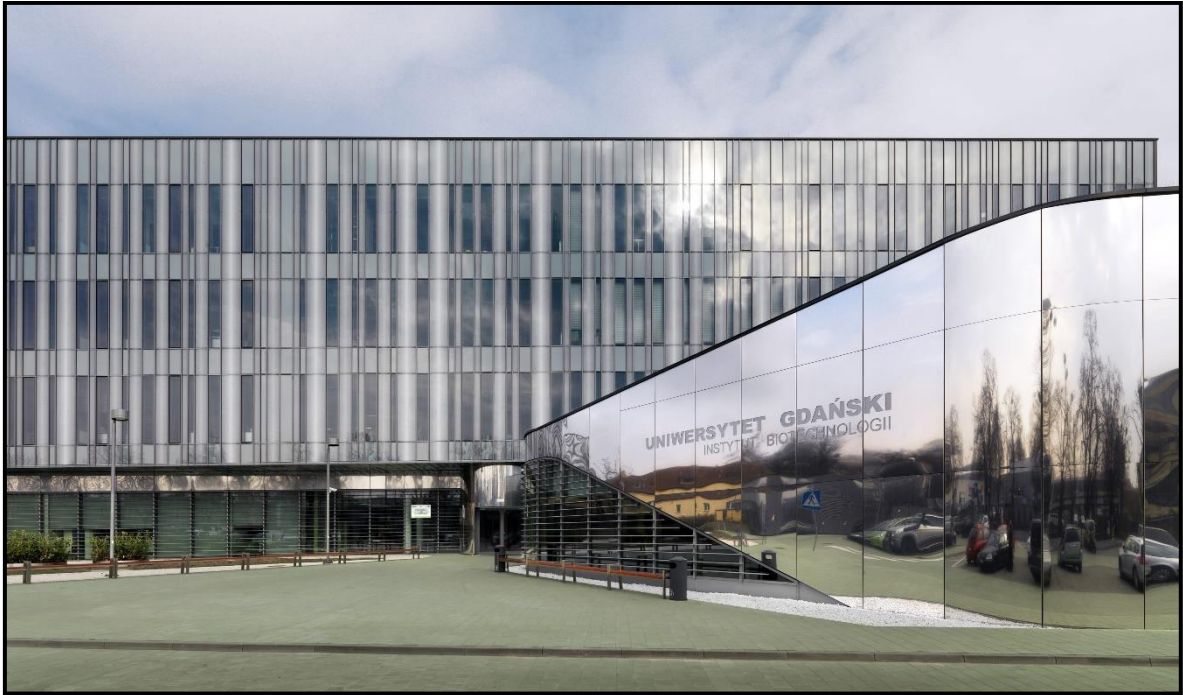


Figure 3.9: Warsztat Architektury, Faculty of Biotechnology Building.

Source: (<https://divisare.com/projects/315784-warsztat-architektury-faculty-of-biotechnology-building>)



Figure 3.10: Alamance Community College Accelerates Investment in Biotech.

Source: (<https://alamancecc.edu/center-of-excellence-site/our-facilities-technology/>)

3.5 THE IMPORTANCE OF FACTORY ARCHITECTURE AND DESIGN

For industrial buildings to be useful and effective, factory architecture and design are crucial. (Usländer et al., 2021) Historically, the aesthetics and design of industrial buildings were neglected in favor of functionality and cost-effectiveness. (Chen & Hu, 2022) But, as building manufacturing has become more industrialized and has placed a greater emphasis on energy-efficient structures, factory architecture and design has grown in significance.

Factory design can greatly benefit from digital twin (DT) models' modular parameterized architecture. Examples of contemporary industrial structures that put an emphasis on design and innovation while preserving utility and cost effectiveness are smart factories or Industry 4.0. Factors like heterogeneous factories, virtual production networks, self-interested factories as production agents, the responsibility of factories to their region, transportation between factories, networks with open shops, parallel machine environments in factories, production network efficiency, and the integration of equipment in the production line should all be taken into account to make sure that factories are both functional and sustainable. Prefabrication can also drastically lower energy use and trash output during manufacturing building.

Elforгани and Rahmat (2019) also claim that a building's "green" component is mainly influenced by its architectural, mechanical, and electrical features. For instance, a factory's carbon emissions can be significantly reduced by increasing insulation, harnessing natural light, and using renewable energy sources like solar and wind power. (Gu et al., 2018) In conclusion, the industrial building sector is rapidly changing, and designing functional and sustainable factories becomes more important.

3.6 THE PHILOSOPHY OF MACHINES AND EQUIPMENTS IN THE FACTORY

Since the Industrial Revolution, the function of machinery in industrial buildings has changed substantially, with automation and robotics becoming more and more common in contemporary companies. (Fonseka et al., 2020)

Machines in factories are designed with the goal of maximizing productivity and efficiency while utilizing technology to enhance the manufacturing process. It is crucial to take into

account elements like depreciation rates and technological improvements when calculating the influence of machinery on industrial buildings.

The development of factory automation and robotics has been fueled by the Fourth Industrial Revolution, or Industry 4.0, which has been made possible by technological advancements like the Internet of Things, artificial intelligence, cloud computing, integrated systems, and sensors.

The smart factory, which integrates equipment and systems using information and communication technology (ICT), the Internet of Things (Feng & Audy, 2020), and data analytics to build a fully automated and intelligent production system, is one of the key components of Industry 4.0.



4. CASE STUDIES

In the field of industrial building design, understanding the connectivity and natural flow of a building's spaces is crucial for creating efficient and effective production spaces. To this end, the space syntax method is used to analyze the integration of spaces in the design of industrial buildings. This thesis presents two case studies of industrial buildings that have been analyzed using the space syntax method.

The first case study is the Nitrile Glove manufacturing factory, which has a large construction area and separate floors. The factory is divided into different functional spaces on three floors, including the production area, office area, material packing storage area, final product storage area, laboratory area, and machines and equipment storage area. The factory layout is analyzed using the space syntax method to determine the connectivity and natural flow of each space, both with and without furniture and other elements and each floor is analyzed separately. The analysis is performed using the Depthmap X software, which generates a 2D visual map of the factory layout. Logical methods are used to investigate the findings of the analysis.

The second case study is a textile production factory that has a large flat area. This flat area is divided into three separate functional spaces, including the office area, production areas, and storage areas. This case study is selected due to its plan shape. The production areas are further divided into a dress sewing area, a fabric cutting area, and a textile automatic printing area. The storage areas include the finished product storage area, semi-finished product area, accessory storage area, and fabric and raw material storage area. The factory layout is analyzed using the space syntax method to determine the connectivity and natural flow of each space, both with and without furniture and other elements. The analysis is performed using the Depthmap X software, which generates a 2D visual map of the factory layout. Logical methods are used to investigate the findings of the analysis.

In these cases, the first case study is selected due to its layout. This building has 3 floors in all, and the analysis has been done on each floor separately. In the middle of the factory's ground floor area, there is a central production area, surrounded by other areas such as warehouses, laboratories, and office areas. In the second case, in this factory, the field layouts are planned consecutively from left to right. It is not planned as a central production

area or storage area. In order to reach the rightmost one from the leftmost one, it was necessary to pass through all the fields. For this reason, a factory with a different layout compared to the other case study was chosen. In both case studies, the space syntax analysis is conducted in terms of connectivity and natural movement. The visual maps generated by the Depthmap X software provide a comprehensive overview of the spatial layout of the factories, highlighting the connectivity and natural movement between different spaces. The analysis is performed both with and without furniture and other elements to provide a complete picture of the factory layout. The logical method is used to investigate the findings of the analysis and provide insights into the design and layout of industrial buildings.

4.1 NITRILE GLOVE MANUFACTURING FACTORY

The Nitrel Glove manufacturing factory is a large industrial building that has been chosen as a case study for research purposes. The factory has a construction area of 14,715 square meters, and it is located in an area that is conducive to industrial activities.

The factory has three floors, each with a different layout and purpose. As illustrated in the figure 4.1, the ground floor is the main production area of the factory, and it occupies the central part of the floor. The left side of the floor is dedicated to office space, material packing storage, final product storage, and laboratory areas. On the top of the factory, machines, equipment storage, and shelter areas are located, while on the left part of this floor, raw material stock areas and loading/unloading areas are situated.

The first floor (Figure 4.2) is also used for production, and it occupies the central area of the floor. The office area is situated on the left side of the floor, while the temporary storage area is located on the top of this floor.

The second floor (Figure 4.3) is dedicated to office space, and it extends vertically from the other floors. The office area is located on the left side of the floor, while the dining hall space is located on the top of the space.

In this case study, all floors of the factory are analyzed using the space syntax method, which focuses on the connectivity and natural movement of the spaces, including furniture and equipment. The analysis is carried out separately for each floor, and the results are investigated using logical methods.

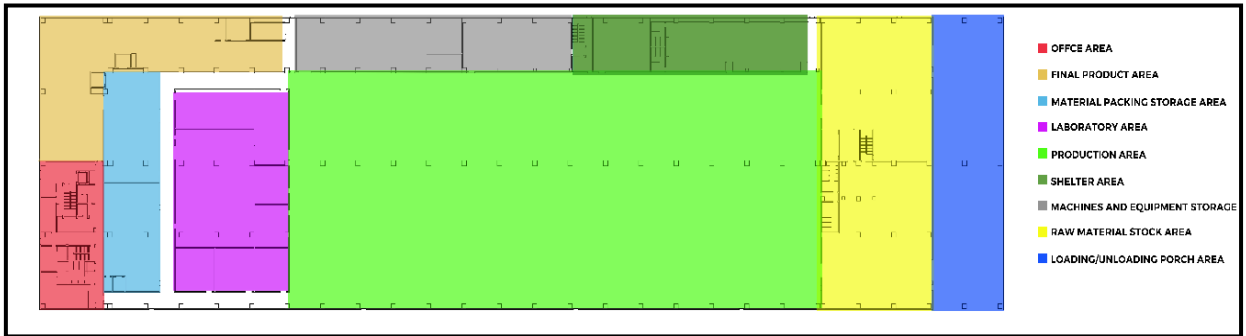


Figure 4.1: General Arrangement of Different Spaces on the Ground Floor.
(Adopted and modified by author)

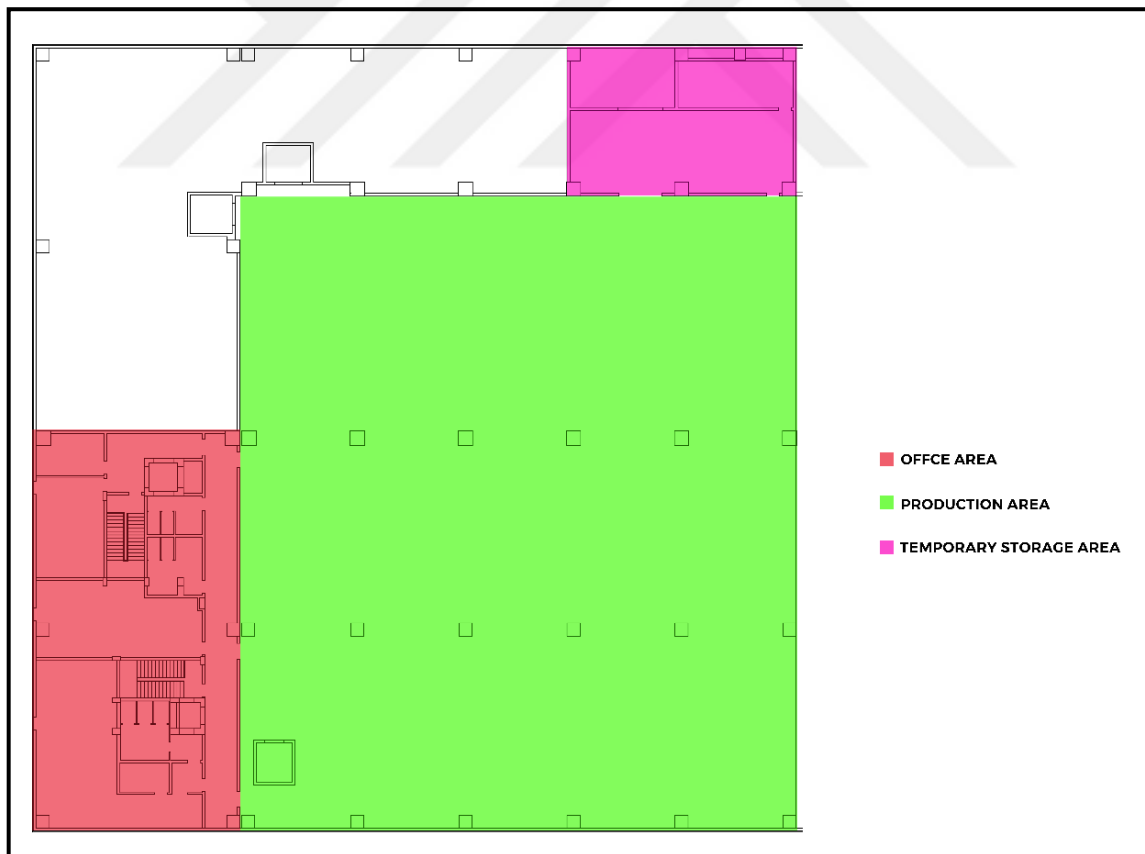


Figure 4.2: General Arrangement of Different Spaces on the Ground Floor. (First Floor).
(Adopted and modified by author)



Figure 4.3: General Arrangement of Different Spaces on the Ground Floor (Second Floor).

(Adopted and modified by author)

4.1.1 Ground Floor Connectivity Analysis without Furniture

According to Figure 4.4, the furniture is not included, the visual graph shows a strong connectivity space in the middle of the factory, indicating that this area is highly connected to other parts of the factory. This could be due to the location of main production areas or the central location of the factory's infrastructure. The edges leading to and from this central space may be thicker or darker, indicating the importance of these connections for the movement of people, materials, and products within the factory. In the connection part of center space (production line) with the raw material stock part, it can be also observed that those parts are the strong connection nodes between the production part and storage area. Other areas of the factory, such as the product warehouse or loading areas and office parts, are less connected areas to the central space and to each other, depending on their location

and function. The visual graph also reveals potential bottlenecks or areas where movement is restricted or difficult like corridors in laboratory and office areas.

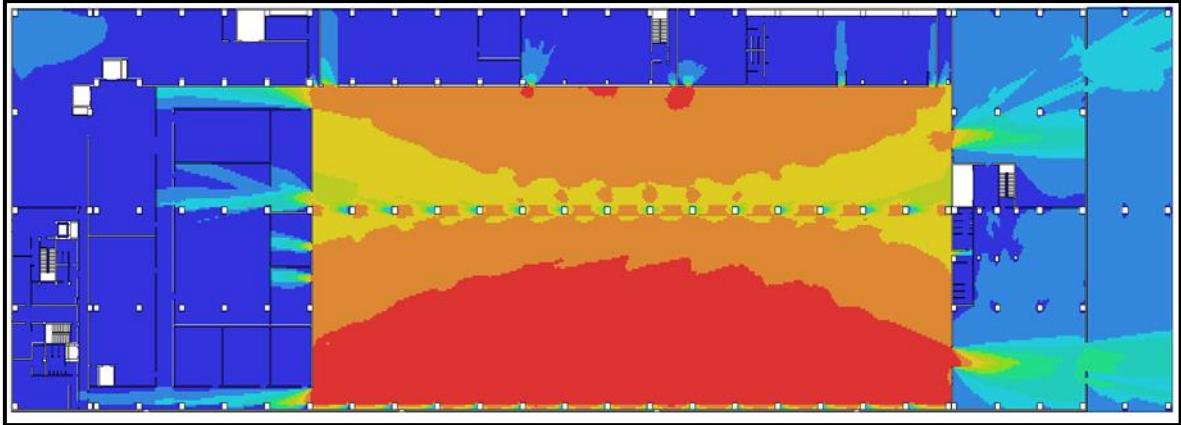


Figure 4.4: Ground Floor of the Factory (Unfurnished Connectivity Analysis).
(Adopted and modified by author)

4.1.2 Ground Floor Connectivity Analysis with Furniture

This visual graph of connectivity analysis (Figure 4.5) that includes the furniture in all parts, such as the office, production area, warehouse, and loading areas, shows a different pattern of connectivity compared to the unfurnished case. In this case, the furniture and equipment acts as physical barriers or enablers of movement and communication between different areas of the factory. As the production area is located in the middle of the factory, the visual graph shows a high density of connections and centrality in this area, indicating its importance for the movement and flow of materials and products. However, the visual graph also shows a more distributed pattern of connectivity, as the furniture and equipment in other areas of the factory affect the accessibility and connectivity of those areas. The dark areas in the unfurnished case may appear brighter in the graph, indicating that the connectivity and accessibility of those areas have improved with the addition of furniture and equipment. For example, the office area is more connected to the production area and the loading area, as the furniture and equipment in the office facilitates communication and coordination between these areas. Similarly, the warehouse of raw material area is more connected to the loading/unloading area, as the furniture and equipment in the warehouse may enable the efficient movement and storage of products.

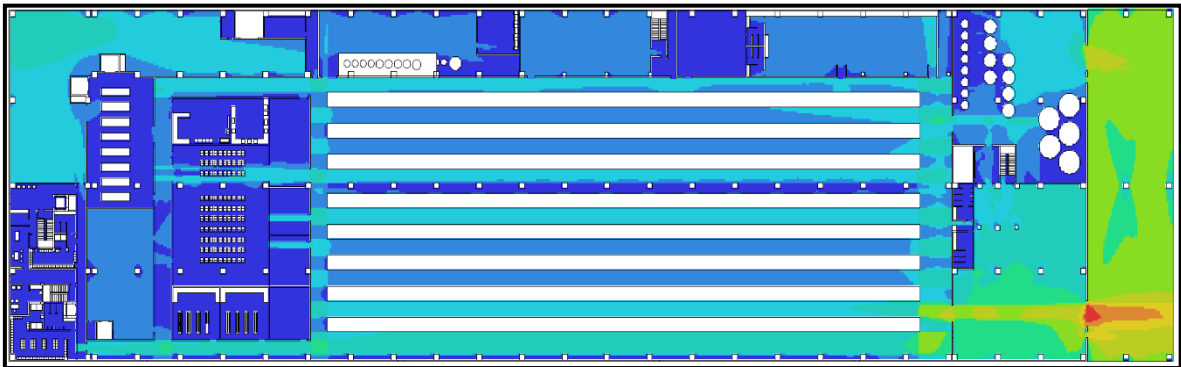


Figure 4.5: Ground Floor of the Factory (Furnished Connectivity Analysis).

(Adopted and modified by author)

4.1.3 First Floor Connectivity Analysis without Furniture

Visual graph of connectivity analysis of the factory's first floor (Figure 4.6), without including furniture and equipment, shows a network of nodes and edges that represent different areas of the floor and the connections between them. In this case, the production area appears to be the most important area, with a strong point of connection that is highlighted as a reddish area in the graph. The corridor that connects the office area with the production area is also clearly visible in the graph, with the color of the edges near the openings between those two spaces, indicating a strong point of connection between these areas. The office area, on the other hand, appears mostly dark blue, which indicates that it is not a major point of connection in the analysis. The cafeteria area in the middle of the office part appears to be an important point of connection for the office area, as indicated by the lighter blue color of the edges leading to and from this area. The entrance to the cafeteria is also highlighted as a lighter area in the graph, indicating its importance as a connection point for the office area. On the top of the graph, it can be observed that the area that is for transferring the products to the loading area, acts as a connection space.

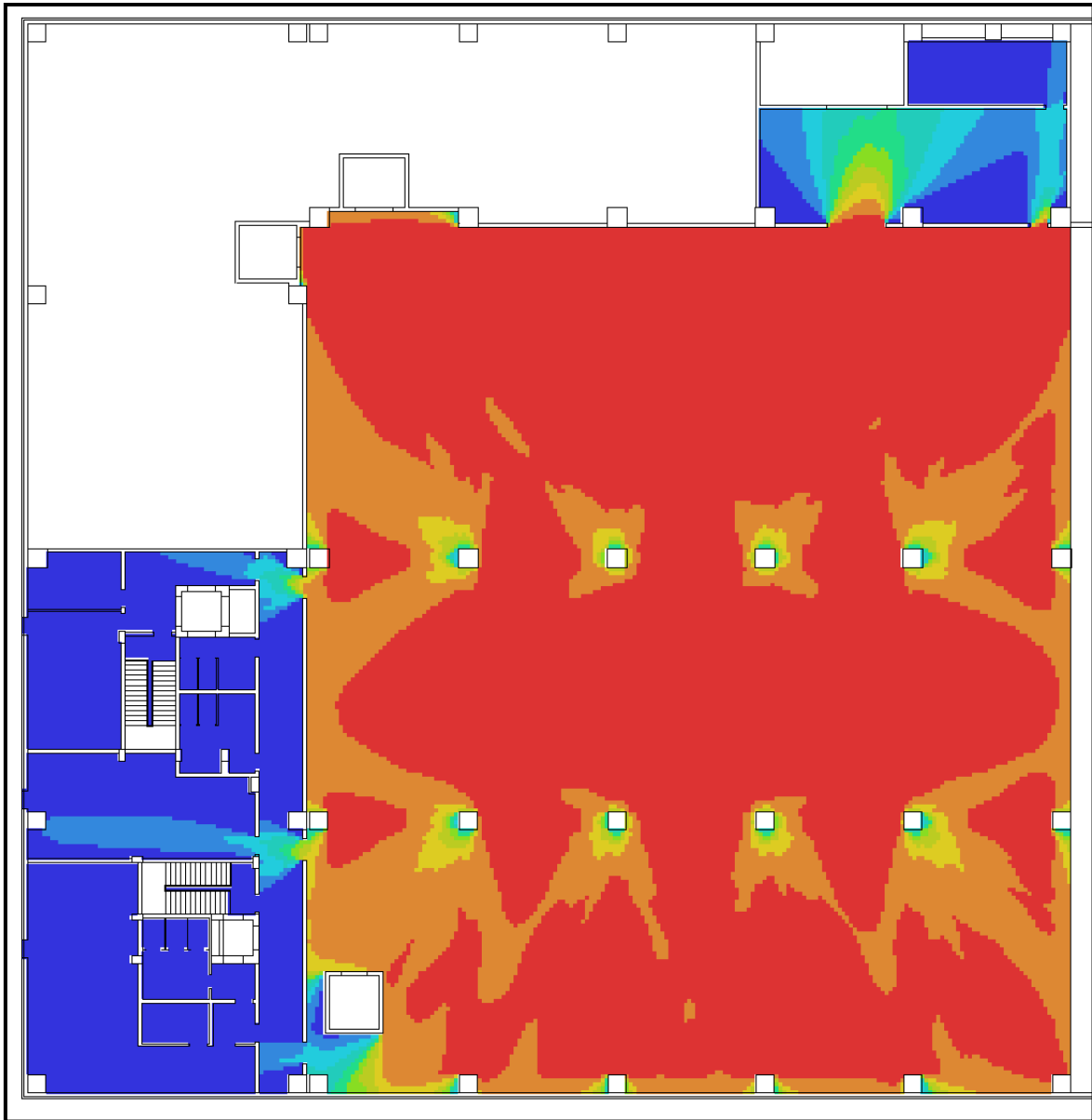


Figure 4.6: First Floor of the Factory (Unfurnished Connectivity Analysis).

(Adopted and modified by author)

4.1.4 First Floor Connectivity Analysis without Furniture

The furnished version of the connectivity graph of the first floor of the factory (Figure 4.7) highlights the impact of furniture and equipment placement on the overall connectivity pattern of the space. As it noted, the dense connectivity that was present in the middle of the production area in the unfurnished version is now separated due to the placement of machinery and equipment. However, despite this separation, it can still be observed that

there are connection points at the end of each corridor formed by the machinery, as indicated by the red color in those areas.

This suggests that the placement of machinery and equipment can have a significant impact on the flow and movement within the space, and that careful consideration of these factors is important in optimizing the layout and organization of the space. The corridor that connects the production area and the office area is also highlighted as a connection area, with a light blue color indicating a medium degree of connectivity compared to the other parts of the area. This suggests that the placement of this corridor is effective in facilitating movement and flow between the two areas, and that it may be a key element in optimizing the overall connectivity of the space. The cafeteria region is also noted as a central connection area in the office part of the space, with a high degree of connectivity indicated by a light blue color. This highlights the importance of communal spaces and areas of congregation in facilitating movement and interaction within the space. Finally, the green color corridor at the bottom of the production area is noted as the main connection path between the office and production areas. This suggests that this corridor is a key element in facilitating movement and flow between these two areas, and that its placement and design may have significant impacts on the overall connectivity and efficiency of the space.

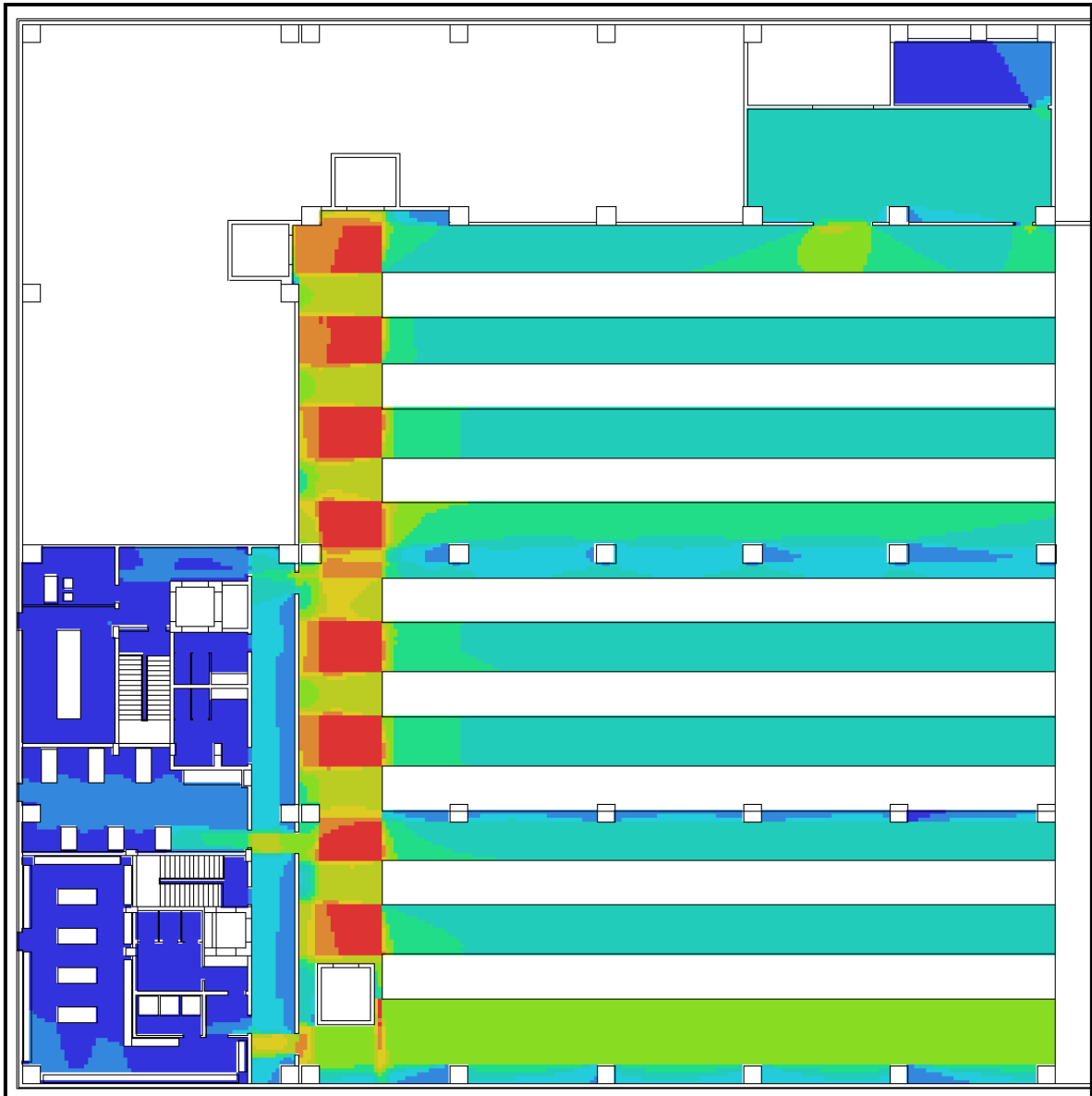


Figure 4.7: First Floor of the Factory (Furnished Connectivity Analysis).

(Adopted and modified by author)

4.1.5 Second Floor Connectivity Analysis without Furniture

In this analysis, the entrance to the dining hall appears to be a strong point of connection, with a reddish area at the top of the plan that spreads through the middle of the hall and continues to the end of the hall. This strong connection area appears to be consistent across all space, and is highlighted in a light yellow color at the end of the dining hall. The corridor that connects the dining hall and office parts is also visible in the graph, with the color of the edges indicating a point of connection between these areas. However, this connection area

is not as strong as the entrance to the dining hall, and is represented by a light blue color. In addition to these main connection areas, the visual graph also shows smaller corridors and offices that connect other rooms to each other. These connection areas are highlighted in different colors, depending on their strength and importance in the overall network (Figure 4.8).

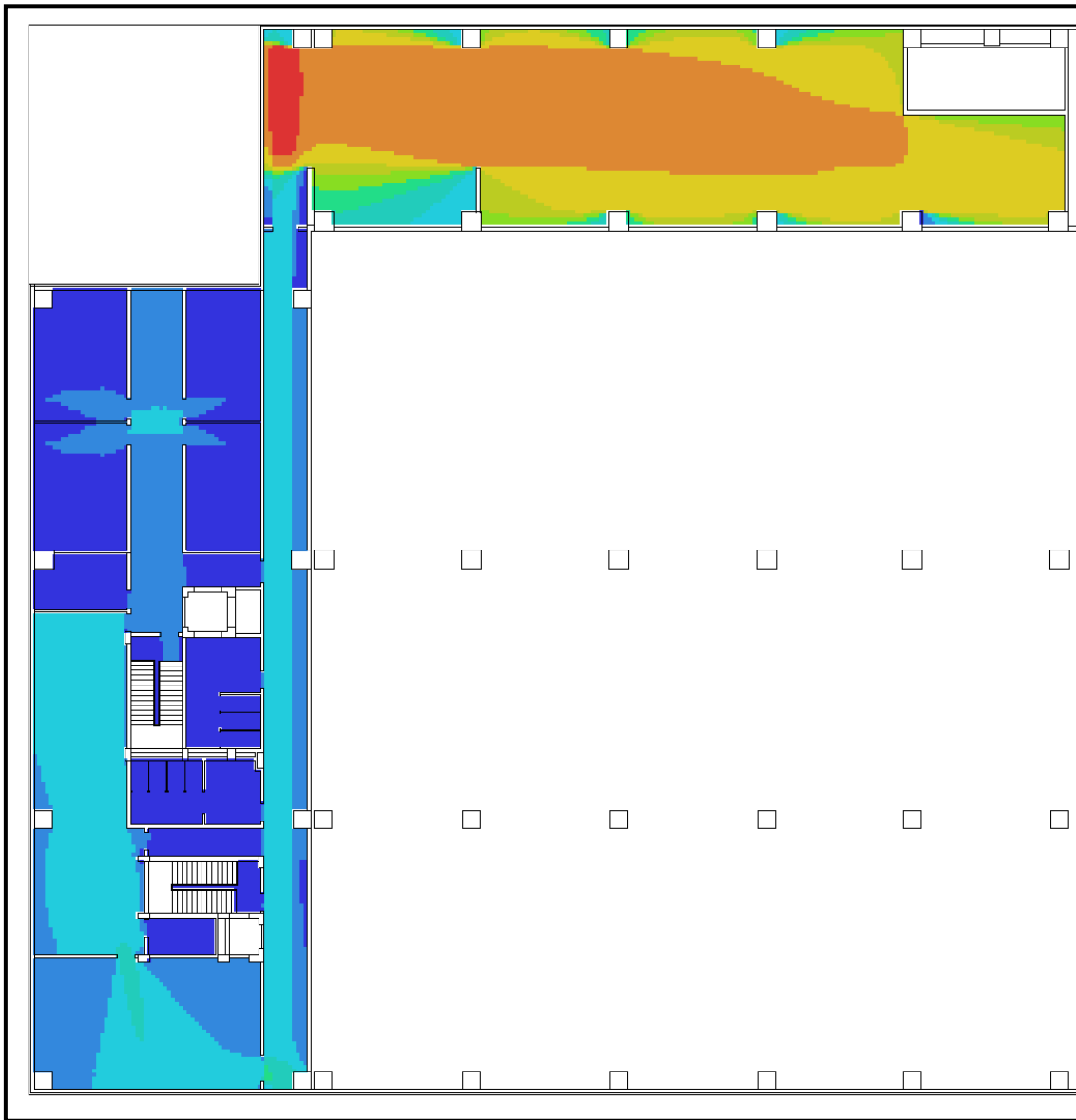


Figure 4.8: Second Floor of the Factory (Unfurnished Connectivity Analysis).
(Adopted and modified by author)

4.1.6 Second Floor Connectivity Analysis with Furniture

In the furnished version of the connectivity graph of the second floor of the factory (Figure 4.9), the presence of furniture can be seen to affect the distribution and strength of connection points in different areas. The dining hall, which was a strong point of connection in the unfurnished version, still appears as a reddish area at the entrance of the hall. However, the presence of dining tables in that area seems to have a significant impact on the connectivity pattern, with the color of the edges indicating a point of connection becoming more blue than yellow or red.

In other areas of the floor, the presence of furniture can also be seen to affect the connectivity pattern. For example, in office areas where there is more furniture, the color of the edges tends to be darker, indicating a lower degree of connectivity. This is because the presence of furniture can create barriers that impede movement and limit access to different parts of the space. The change in color of the corridor from light blue to green, as observed in the furnished version of the connectivity graph of the second floor of the factory, indicates a change in the strength and nature of the connection between the office part and the dining hall. In this case, the corridor is serving as a strong and efficient connection line between the two areas, with a higher degree of connectivity than some other parts of the floor.

The green color suggests that this connection line is especially strong and efficient, indicating a high degree of flow and movement through the corridor. This may be due to factors such as the width of the corridor, the location of entrances and exits, or the absence of obstacles or barriers that would impede movement. The change in color from light blue to green also highlights the importance of considering the context and layout of the space when analyzing connectivity patterns. While some areas may appear to be strong points of connection in isolation, the presence of corridors and other connecting elements can significantly affect the overall connectivity and efficiency of the space.

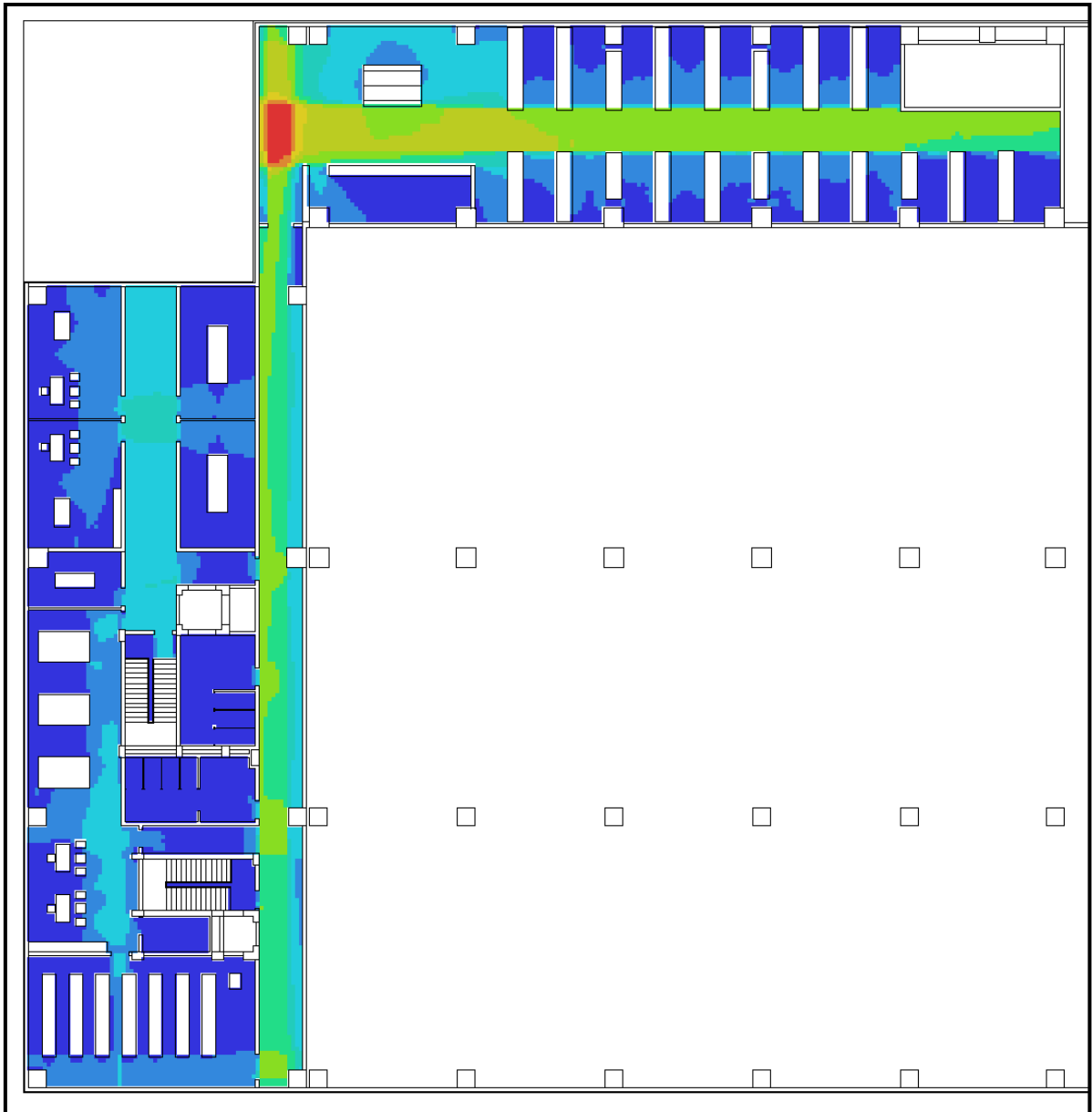


Figure 4.9: Second Floor of the Factory (Furnished Connectivity Analysis).

(Adopted and modified by author)

4.1.7 Ground floor Natural Movement analysis without furniture

Based on the visual graph provided, it appears that the production area is the most densely populated part of the floor (Figure 4.10), and that the center of the production area is the most connected area.

Additionally, it appears that agents are less likely to move to other areas of the floor, as these areas are colored in a darker shade of blue. This could indicate that the layout of the floor is

not optimized for movement between different areas, or that there are other barriers preventing agents from moving to these areas.

The final product storage and exporting area is also an area that agents choose to move to, and it is colored in a light blue shade. This suggests that this area is well-connected and accessible, and that agents find it easy to move to this area.

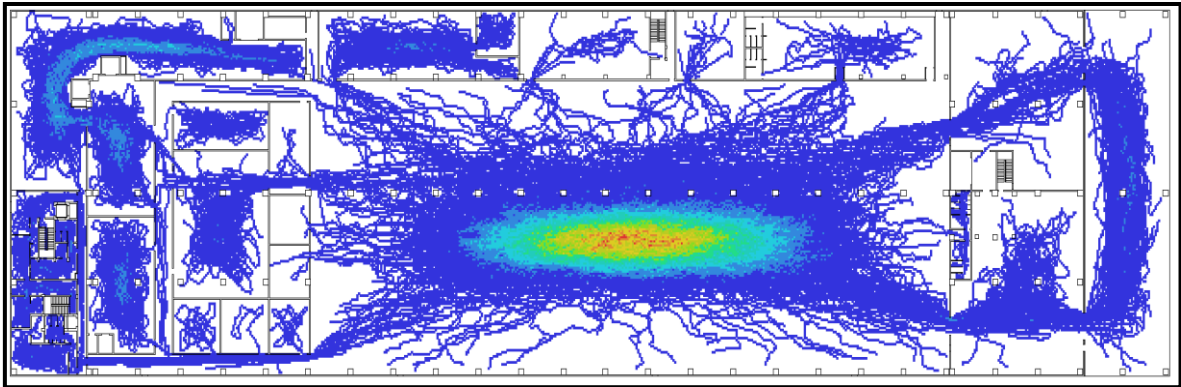


Figure 4.10: Second Floor of the Factory (Unfurnished Natural Movement Analysis).

(Adopted and modified by author)

4.1.8 Ground floor Natural Movement Analysis with Furniture

In the furnished case of the Natural movement visual map analysis of the factory's ground floor, it is interesting to note that the density of the central part of the factory, which is the production area, is spread throughout the entire area due to the machine lines. The machine lines act as the barrier for the movement circulation and change the way of agent natural movement. Additionally, there appears to be a central path between the machine lines that serves as a connection corridor between the left and right sides of the factory. This path appears to be well-connected and easily accessible, and agents seem to be willing to choose that path for their movements.

It can be observed that agents are guided to certain areas due to the locations of furniture and other objects on the floor. It is important to note that areas that were not originally chosen by the agents for movement have changed color from dark blue to green and even yellow in the center of the spaces. This suggests that the layout of furniture and other objects can have a significant impact on how agents move throughout the space. Furthermore, the raw material storage and loading area appears to be a popular area for agents to circulate in,

indicating that this area is well-connected and easily accessible. The final product storage and exporting area also appears to be greener in this case than in the unfurnished case, suggesting that this area is well-optimized for movement and circulation (Figure 4.11).

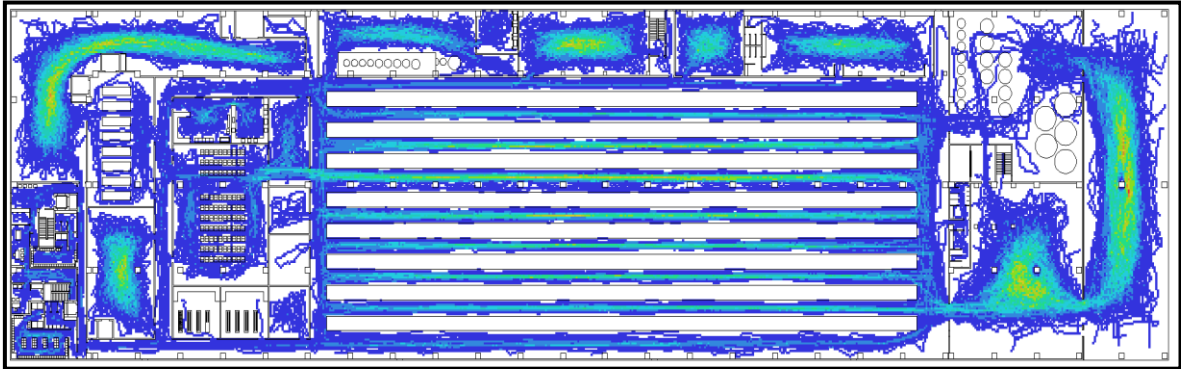


Figure 4.11: Ground Floor of the Factory (Furnished Natural Movement Analysis).

(Adopted and modified by author)

4.1.9 First floor Natural Movement Analysis without Furniture

Based on the visual map analysis of the factory's first floor, it can be seen that the production area is the central point of activity with the highest density of natural movement. This is likely due to the fact that it is the primary area where work is being done, and therefore agents are naturally drawn to this area. Other areas of the factory show low levels of natural movement, with most areas displaying a dark blue color indicating that agents are not willing to move through those areas. This suggests that the layout of the factory may not be optimized for efficient movement, and that there may be bottlenecks or other issues that are preventing agents from moving through these areas.

In the office area, there is a light blue spot in the middle of the dressing room of workers which suggests that agents choose to move in that area. This may be due to the fact that the dressing room is a high-traffic area where workers gather to change clothes or rest during breaks.

On the top floor of the factory, the temporary storage area is displayed as the less preferred area for movement by the agents. This may be due to the fact that it is not a primary area for work, and therefore agents are less likely to need to move through this area. Alternatively, it may be an indication that the layout or design of the temporary storage area is not optimized for efficient movement (Figure 4.12).

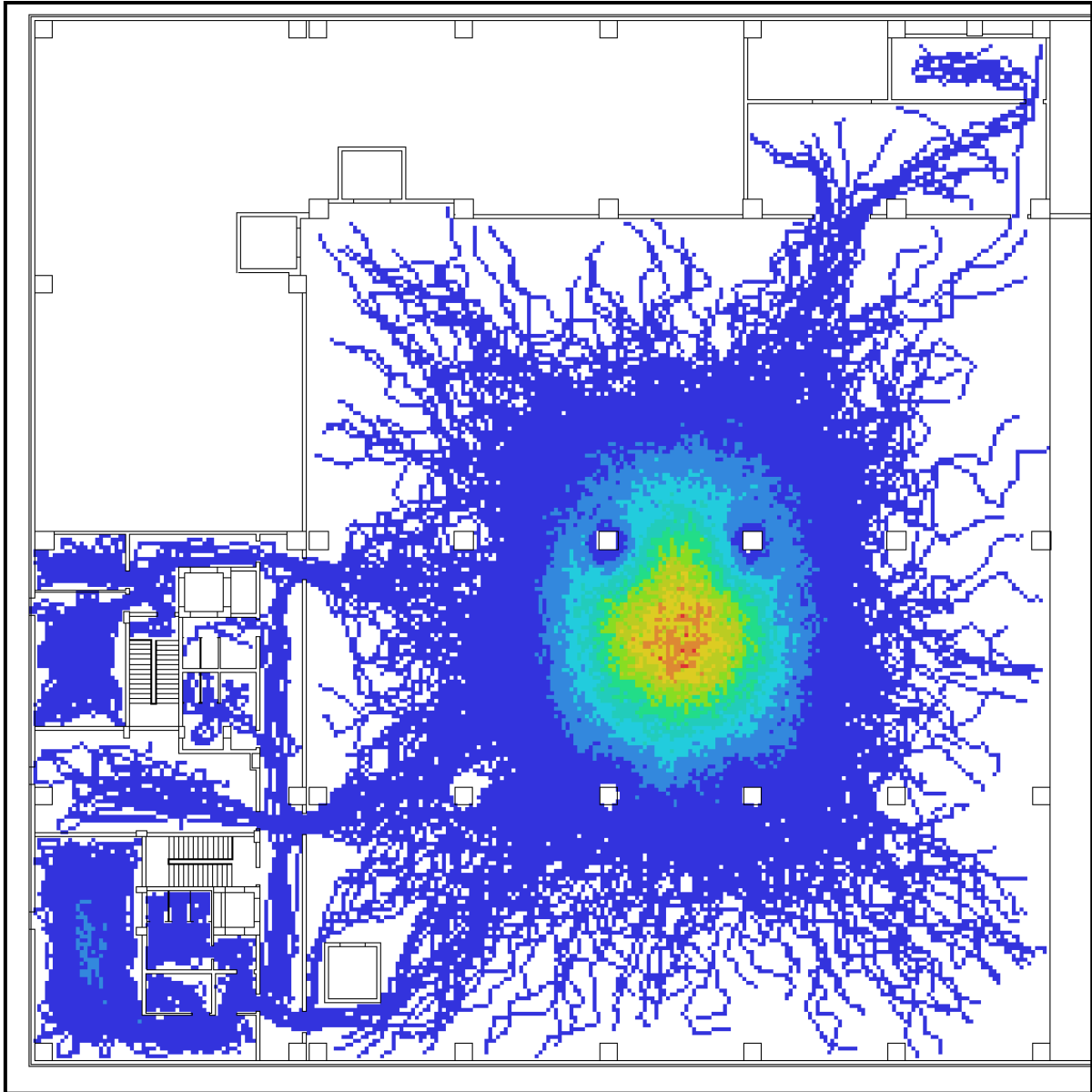


Figure 4.12: First Floor of the Factory (Unfurnished Natural Movement Analysis).
(Adopted and modified by author)

4.1.10 First Floor Natural Movement Analysis with Furniture

In the production area, the movement of agents is primarily concentrated in the corridors that are shaped by the location of production line machines. The reddish and orange points in the center of the two middle corridors could be where agents frequently converge or connect with each other. The main corridor at the start point of the machine is green, indicating that agents tend to choose this path for moving through the production area.

In the office part, the main corridor connecting the production area and the office area is light blue, indicating that agents prefer to use this path for movement through the office. The density of movement in the dressing room area is also spread out due to the presence of a wardrobe acting as a barrier.

Additionally, the temporary storage area on the top floor appears to be more crowded with movement, with the central part of the area colored orange (Figure 4.13).

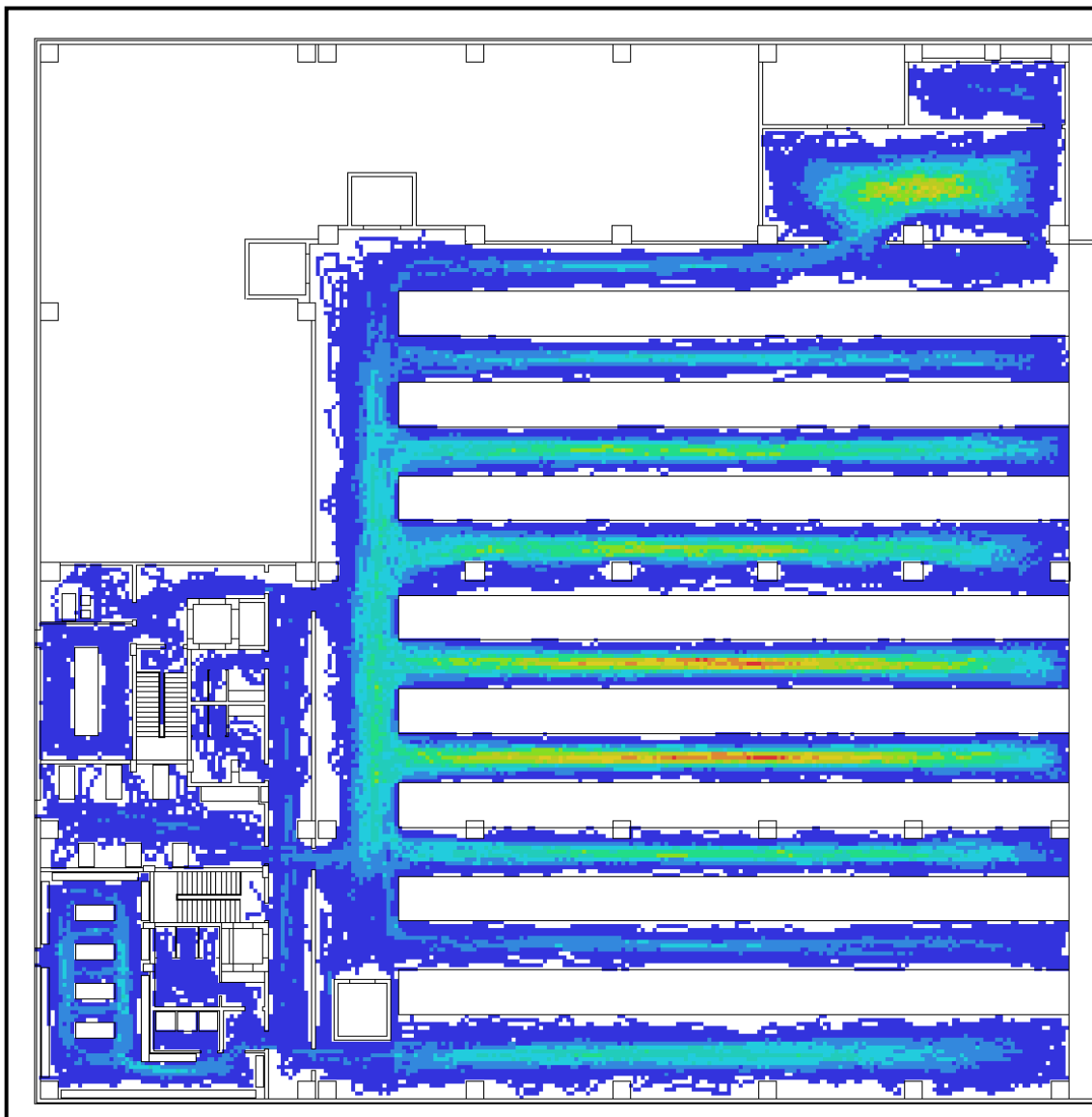


Figure 4.13: First Floor of the Factory (Furnished Natural Movement Analysis).

(Adopted and modified by author)

4.1.11 First Floor Natural Movement Analysis without Furniture

Based on the visualization, there seems to be a crowded area in the middle of the dining hall, with a reddish color in the center. This crowded area in the center of the dining hall may indicate that agents (presumably people) tend to converge or intersect at this point. It could be a common meeting spot or an area where people frequently cross paths on their way to different parts of the dining hall.

The map shows that this corridor is primarily used for moving circulation, with no indication of agents stopping in this area.

The light blue color in this area suggests that agents tend to move quickly and efficiently through this corridor, without any significant interruptions. This could indicate that the primary function of this area is to facilitate movement between the dining hall and the office parts of the building.

There is a significant amount of moving circulation in the secondary corridors between office rooms, with intersections in the middle of the corridors indicating that agents frequently cross paths in these areas.

There is also a density of movement in the middle of the office room that connects to the training room, as well as in the opening that connects these two areas. This suggests that these areas are popular points of intersection or connection for agents moving through the office area. Additionally, there seems to be a connection point in the middle of the training room that is shaped by agent movement, as indicated by the light blue color. However, it seems that other parts of the office area are not as frequently used by agents for movement, as indicated by the dark blue color (Figure 4.14).

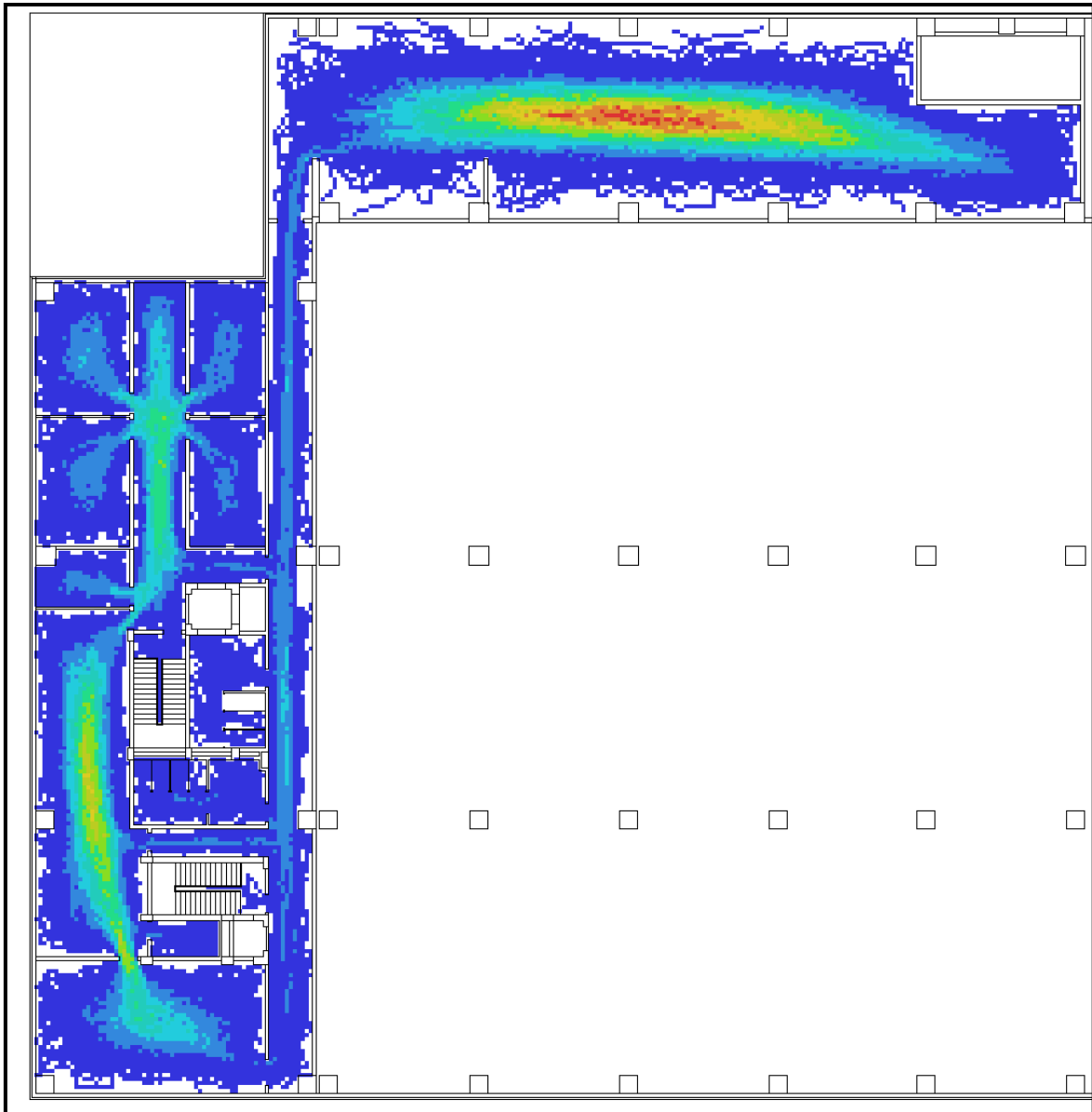


Figure 4.14: Second Floor of the Factory (Unfurnished Natural Movement Analysis).
(Adopted and modified by author)

4.1.12 First Floor Natural Movement Analysis with Furniture

The map illustrates in the furnished version, the density in the middle of the dining hall spreads horizontally due to the location of the tables. It can also be observed that there are areas in the dining hall that were not scanned by the agents in the unfurnished version. But, in the furnished case agents walk through these areas, but not constantly. This could suggest that these areas are less popular or less frequently used by agents for movement.

It can be seen that there is a change in color in the main corridor of the floor in the furnished case. The lighter blue and green colors suggest that this area is used more frequently by agents for their movement circulation. This change in color could indicate that the main corridor is an important pathway for agents moving through the building, and that it is used regularly to access different areas of the building. The lighter blue color indicates faster movement, while the green color may suggest a more relaxed or leisurely pace.

Visual analysis of the secondary corridors in the office area of the building shows that these corridors seem to have a crowded agent circulation compared to other parts of the building, indicating that they are important pathways for agents moving through the office area.

The density and crowdedness in the training hall and in the room that connects the secondary corridor may be due to the presence of furniture that acts as a barrier, guiding agents to change their direct moving path. This could be a factor in avoiding crowdedness in those areas, as agents are forced to change their direction and navigate around the furniture (Figure 4.15).

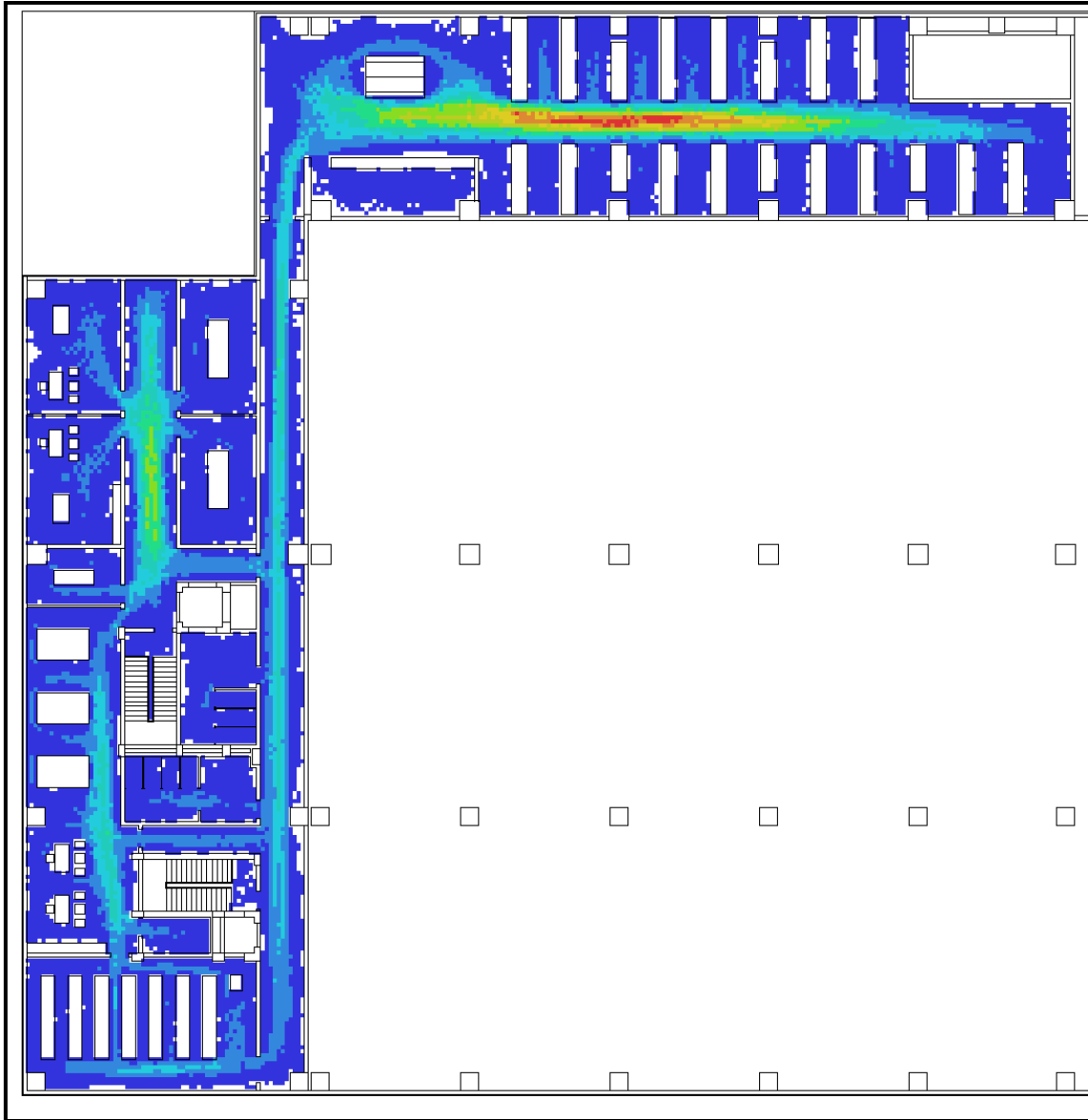


Figure 4.15: Second Floor of the Factory (Furnished natural Movement Analysis).

(Adopted and modified by author)

4.2 TEXTILE PRODUCTION FACTORY

The Textile production factory is a large industrial building that serves as the second case study for research purposes. The factory has a large floor area and is divided into three separate functional spaces, namely the Office area, the production areas, and the storage areas.

As shown in figure 4.16, the main Office area is located in the left-bottom corner of the factory. The production areas are divided into three different sections. The dress sewing area

is located on the left side of the factory floor, while the fabric cutting area is located in the middle-bottom part of the floor. The textile automatic printing area is located on the top-middle part of the floor.

The storage areas are also divided into different sections. The finished product storage area is located on the top-left part of the floor, while the semi-finished product area, accessory storage area, and embroidery workshop area are located in the middle part of the floor. The fabric and raw material storage area is located on the left side of the factory floor.

In this case study, every space in the factory is analyzed using the space syntactic technique to determine the connection and natural flow of each area, both with and without furniture and other elements. Logical methods are used to investigate the findings of the analysis.

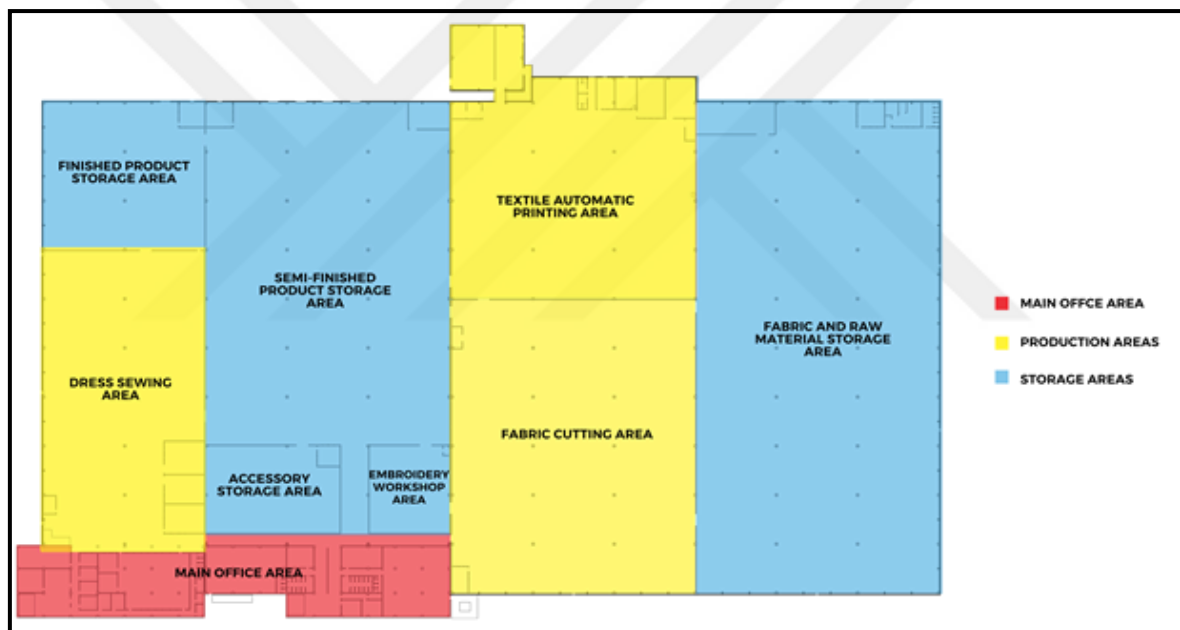


Figure 4.16: General Map of the Factory.

(Adopted and modified by author)

4.2.1 Main Office Area Connectivity Analysis without Furniture

According to the Figure 4.17, the Office area is the isovist part of the factory, meaning that it has no direct connections with other areas of the building. This area appears as a dark blue color on the connectivity analysis result, indicating that it is a disconnected or isolated part of the factory.

In contrast, connection areas of the office part with other parts, it can be observed that have connection openings that allow for movement between different spaces. These areas appear as brighter blue colors on the connectivity analysis result, indicating that they are non-isovist areas due to their connection points with other parts of the factory. It is important to note that this analysis is based solely on the connectivity of the space and does not take into account other factors such as furniture placement or the actual use of the space.

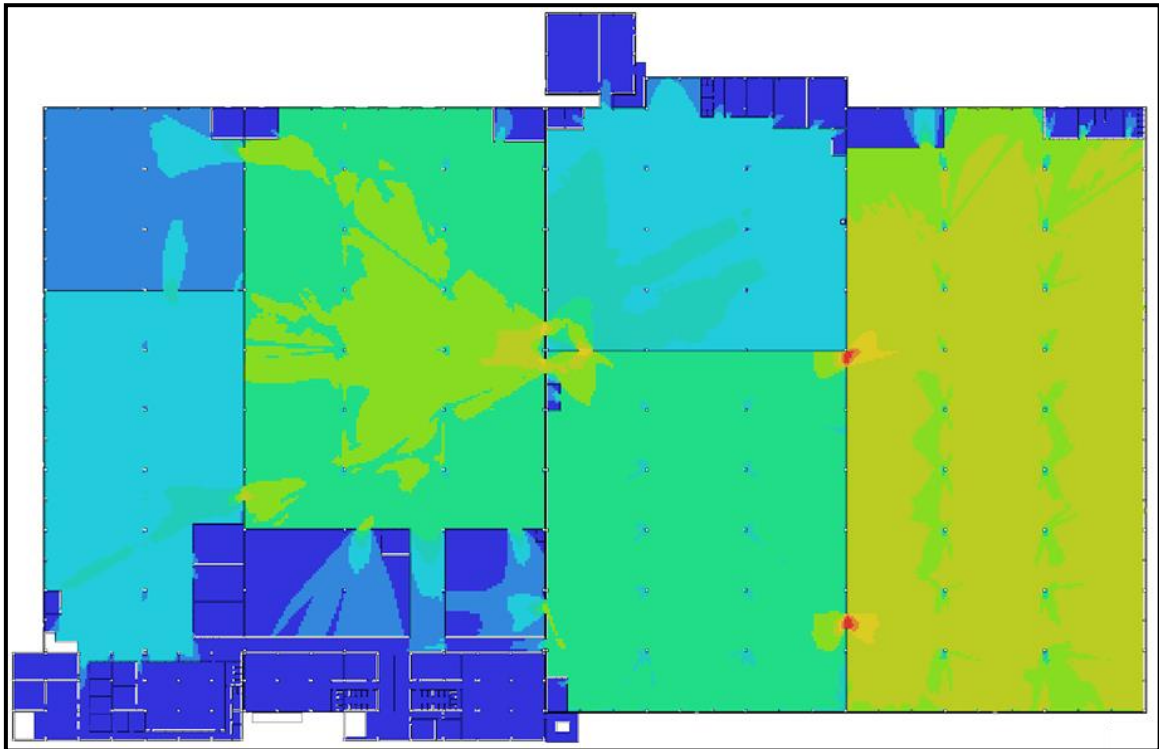


Figure 4.17: Unfurnished Connectivity Visual Map Analysis of the Factory.

(Adopted and modified by author)

4.2.2 Production Areas Connectivity Analysis without Furniture

The factory has three production areas, one for dress sewing on the left side and the other areas for an automatic textile fabric cutting and textile automatic printing areas in the middle. All areas have different results in connectivity analysis. This means that they have different levels of connectivity or connection paths to other areas of the factory. The dress sewing area on the left side of the factory and textile automatic printing area are relatively isolated or have limited connections to the other production area. On the other hand, the automatic

textile Fabric-cutting machine area in the bottom-middle of the factory has more connection paths to the other areas.

The map shows that the dress sewing on the left side of the factory appears as a majority light blue color, indicating that it has few connection paths or openings to other areas of the factory. However, in the middle of the production area, there is a light green path that connects it to the storage area. This light green path indicates that it is a significant connection path that allows for movement between the two areas. Additionally, the opening that connects the finished product storage area and the production area also appears as a light green color on the map, indicating that it is a crucial connectivity point in this area. The office areas in the bottom of the space, have a dark blue color and can be considered isovist areas except for their connection points with the main production area (Figure 4.17).

The connectivity map suggests that the production area of the factory is relatively isolated, with only one significant connection path to the storage area. The opening that connects the finished product storage area and the production area also appears as a key connectivity point on the map (Figure 4.17).

The majority of the textile automatic printing area appears as a light blue color, indicating that it has few connection paths or openings to other areas of the factory. However, there is a light yellow point in the connection area with the semi-finished product storage that appears as a potential connection point. The surrounding areas, including the controlling and monitoring rooms, chemical material storage, and machines panel room, appear as a darker blue color, indicating that they are the most isovist areas in the production area. These areas may have fewer connection paths to other areas of the factory. In the middle of the production space, there is a dark green color, indicating that it may act as a connection path between different areas of the factory. This path is likely to be important in connecting the various production areas and may be used frequently during the production process. The connectivity map suggests that the textile automatic printing area has a limited number of connection paths or openings to other areas of the factory, with the exception of the connection point with the mid-finished product storage (Figure 4.17).

The analysis result of automatic textile fabric cutting area is different from other production areas, as the majority of the area appears as a light green color, indicating that it is the most

connected area in the production spaces. This may suggest that this area has many connection paths or openings to other production areas of the factory. In the connection part with the semi-finished product storage, there is a yellow color point that appears as a potential connection point. This point may play an important role in connecting the automatic textile fabric cutting area with the semi-finished product storage. There are also two red spots in the connection opening between this area and the fabric warehouse area. These spots act as the most connectivity points in this production area, indicating that they may be important connection points for the automatic textile fabric (Figure 4.17).

4.2.3 Storage Areas Connectivity Analysis without Furniture

The warehouse area of the factory consists of three storage areas: the finished products storage area in the top-left corner, the semi-finished product storage area in the top-left side, and the fabric and raw material storage area on the right side of the factory. Each of these areas has a different connectivity potential according to the connectivity analysis map (Figure 4.17).

The majority of the space in the finished products storage area appears to be an isovist area, which means that it is less connected than other areas of the factory. However, there are two light blue colored spots in the connection opening areas with the semi-finished product storage area and the dress sewing area. This suggests that there are some connection paths between these areas that pass through the finished products storage area. Of these two connection points, the one with the semi-finished product storage area appears to be slightly stronger, as there is an orange point in the middle of the connection opening. This may indicate that there is a more direct or important connection path between the finished products storage area and the semi-finished product storage area than between the finished products storage area and the dress sewing area (Figure 4.17).

The connectivity analysis map for the semi-finished Product storage area shows that this area has a dark green color, indicating that it is a relatively strong connectivity point. This means that there are multiple openings that connect this area with other parts of the factory, making it easier for people and materials to move in and out of this area. There is also a light green spot in the middle of the area which is spread throughout the area. This could be because this spot is located at the intersection of several openings that connect this area with

other parts of the factory. This intersection point is likely to be a major thoroughfare within the factory, which means that there will be a lot of foot traffic and material movement in this area. The heaviest connection point in this area is located in the intersection opening with the textile product cutting and textile automatic printing areas. This connection point is colored orange and can be seen as a circular circulation point. This indicates that there is a high degree of connectivity between these areas and the semi-finished Product storage area, making it easier for materials and people to move between these areas. The connectivity analysis map for the semi-finished Product storage area suggests that it is an important and well-connected part of the factory. Its location at the intersection of multiple openings and its strong connection points make it a key area for the movement of materials and people. Additionally, the Accessory storage area and the embroidery workshop area both have dark blue color, which indicates that they are not considered as strong connectivity points. However, there are some light blue spots in these areas that indicate moderate connectivity strength at the connection points and openings with other areas and spaces. This could suggest that while these areas are not major hubs of activity, they still have some importance in the flow of materials and products within the factory (Figure 4.17).

The strong connectivity in the fabric and raw material storage area is for its critical role in the production process. The orange color and strong connectivity analysis in this area suggest that it has strong connections with other parts of the factory. The light green spots around the columns and in the loading/unloading area could indicate potential areas of congestion or bottlenecks in the flow of materials, but their proximity to the strong orange areas suggests that they are still relatively well-connected. The dark blue isovist areas surrounding the office spaces indicate that these areas have limited visibility and may not be easily accessible from other parts of the factory. However, the connection points with the main storage area are still strong, indicating that the offices are still well-integrated into the production process. The strong connectivity in the fabric and raw material storage area is a positive sign for the efficiency of the factory's production processes (Figure 4.17).

4.2.4 Main Office Area Connectivity Analysis with Including Furniture

In this version, it can be observed that most of the space in the Office area has a dark blue color, which represents isovist areas. This means that these spaces cannot be seen from other areas in the factory, providing some level of privacy to the people working in the Office

area. However, there are connection openings and points in the Office area that connect it to other spaces and corridors in the factory. These connection points are represented by a lighter blue color on the connectivity map, which indicates that they are considered to be connectivity paths and points. These areas are not completely isolated and can be seen from other areas in the factory. The furnished version of the connectivity map provides a more detailed view of the Office area and its connectivity with the rest of the factory. The map allows for a better understanding of the spatial relationships between different areas and how they are connected, which can be useful for optimizing workflows and improving overall efficiency in the factory (Figure 4.17).

4.2.5 Production Areas Connectivity Analysis with Including Furniture

In this version of the connectivity map (Figure 4.18), there have been some changes in the connectivity patterns in the three production areas, likely due to the inclusion of furniture in the spaces. It is possible that the presence of furniture has affected the flow of movement and visual connectivity within these areas.

In the dress sewing area, the spaces that are created by the sewing tables and other equipment, as well as the Office parts in the bottom corner, are now considered isovist spaces. This means that these areas have limited visibility to other parts of the factory. However, there is a light yellow spot in the middle right of the area, which is an opening that connects the semi-finished material storage area. This spot shows a high connectivity point compared to other spaces in this area. This spot spreads through the connection area with the finished material storage area and main Office area, creating a connection path on the right side of the dress sewing area with a blue-green color. This blue-green color illustrates the strength of the connectivity in this area (Figure 4.18).

It can be observed that there are several furniture pieces and equipment placed in the textile fabric cutting area, such as cutting tables and machines, which also affect the isovist analysis of the space. This means that the isovist areas in this space are not only shaped by the physical layout of the space but also by the presence of furniture and equipment. Moreover, the connection point between the textile fabric cutting area and the textile automatic printing area is located towards the middle of the cutting area and has a light yellow color, indicating that it is a significant point of connectivity between the two spaces. The color of the area

around this connection point changes to light green, illustrating the connectivity paths that link the two spaces (Figure 4.18).

The textile automatic printing area has a significant connectivity density spot on the left side of the space with light yellow color, indicating that this area has strong connectivity with other parts of the area. The left side of the space is likely where most of the printing machines are located, which would explain the high connectivity density in this area. The connection area between the textile fabric cutting area and the semi-finished Product storage area also has a strong connectivity value, indicated by the orange color in that space. This makes sense as the cutting area is a crucial step in the production process, and a strong connection with the semi-finished product storage area is necessary to ensure a smooth workflow. However, due to the presence of furniture and equipment in the textile automatic printing area, the surrounding areas, such as the offices, chemical and raw material storage, and corners, are isovist areas with low connectivity value compared to other parts of the space. This is because the furniture and equipment create physical barriers that limit visibility and movement, reducing the connectivity of those areas (Figure 4.18).

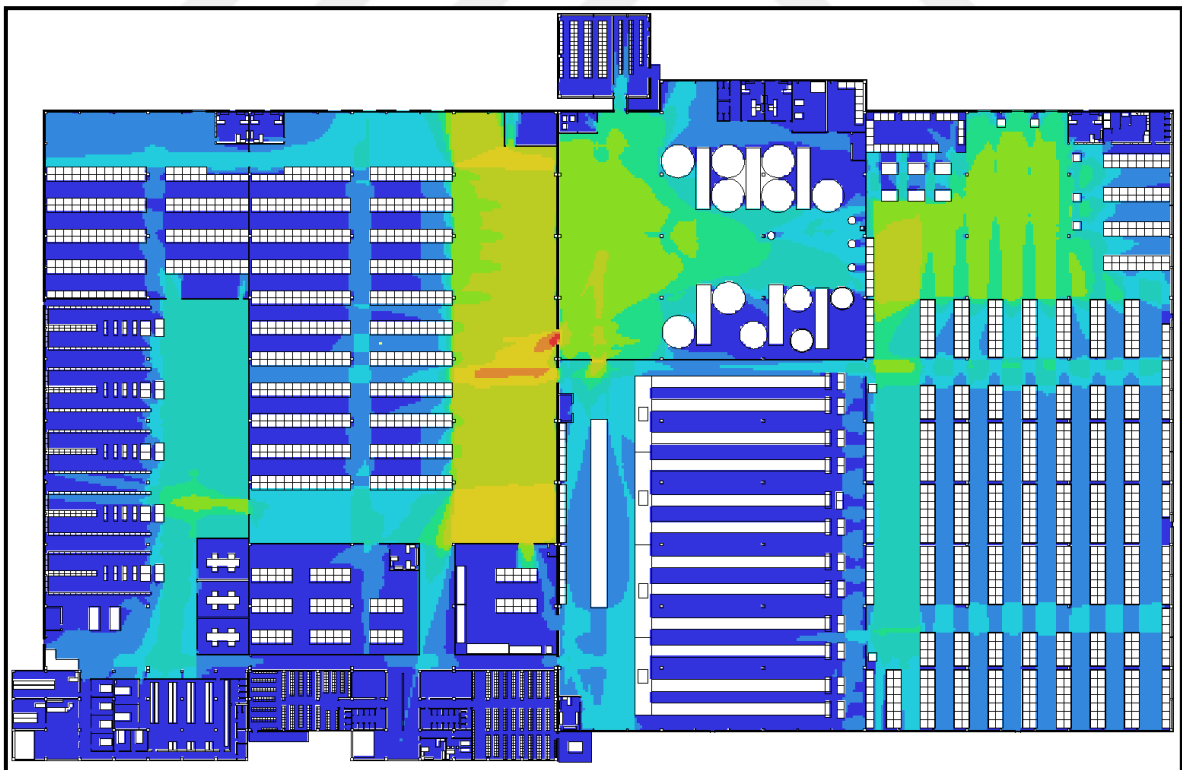


Figure 4.18: Furnished Connectivity Visual Map Analysis of the Factory.

(Adopted and modified by author)

4.2.6 Storage Areas Connectivity Analysis with Including Furniture

The finished product storage area in the furnished version of the connectivity map has a unique shape due to the location of cabinets, which creates an isovist area. The majority of the space in this area has a dark blue color, indicating that it is an isovist area, except for a few spots. These spots are located in the connection areas between the finished product storage area and other spaces, such as the semi-finished product storage and product sewing areas. These spots have a light blue color, indicating that they are connectivity points and paths. The connectivity spot that comes from the connection opening with the semi-finished product storage area is particularly notable. This spot is located on the bottom left side of the finished product storage area and has a light blue color. This suggests that this spot has a high connectivity value and is an important point of connection between the finished product storage area and the semi-finished product storage area. Similarly, in the connection area with the product sewing area, a light blue spot can also be observed, indicating a strong connectivity point between these two areas (Figure 4.18).

Furthermore, in the Accessory storage area and embroidery workshop area, the majority of the space is considered isovist areas with dark blue color, indicating low connectivity value. However, in the entrance of the embroidery workshop, a small area with a yellow color can be seen, indicating a connectivity point. This area serves as a connection point between the embroidery workshop area and the semi-finished Product storage area, which also has a yellow color in the connection point. It is worth noting that these areas are surrounded by cabinets, furniture, and equipment, which reduce the connectivity value and create isovist areas (Figure 4.18).

The furnished version of the fabric and raw material storage area shows that the corridors shaped by the cabinets have low connectivity value, which is similar to the previous cases. Additionally, the Office parts located at the top of the area also have a dark blue color, indicating that those spaces are isovist areas. On the left side of the area, there is a path that intersects with the textile product cutting area, and it has a lighter blue color compared to the rest of the area. This indicates that this area is more accessible than the bottom part of the fabric and raw material storage area. On the top of the area, which serves as the loading/unloading area, there is a huge green spot in the middle. This indicates that this space has the most connectivity value compared to the other areas in the fabric and raw material

storage area. This area is an important hub for connecting the storage area with the other spaces in the facility (Figure 4.18).

4.2.7 Main Office Area Natural Movement Analysis without Furniture

In the unfurnished natural movement analysis of the main Office area, it was found that the agents had a reluctance to move towards the right part of the Office area. This could be due to the absence of any furniture or equipment in that area, making it less appealing for movement. However, there was still some flow observed in the right part of the main Office area, but the movement density in that area was not significant. This can be seen from the dark and light blue colors in that area, which indicate low movement density. The absence of furniture in the main Office area seems to have limited the movement of agents towards the right part of the area (Figure 4.19).

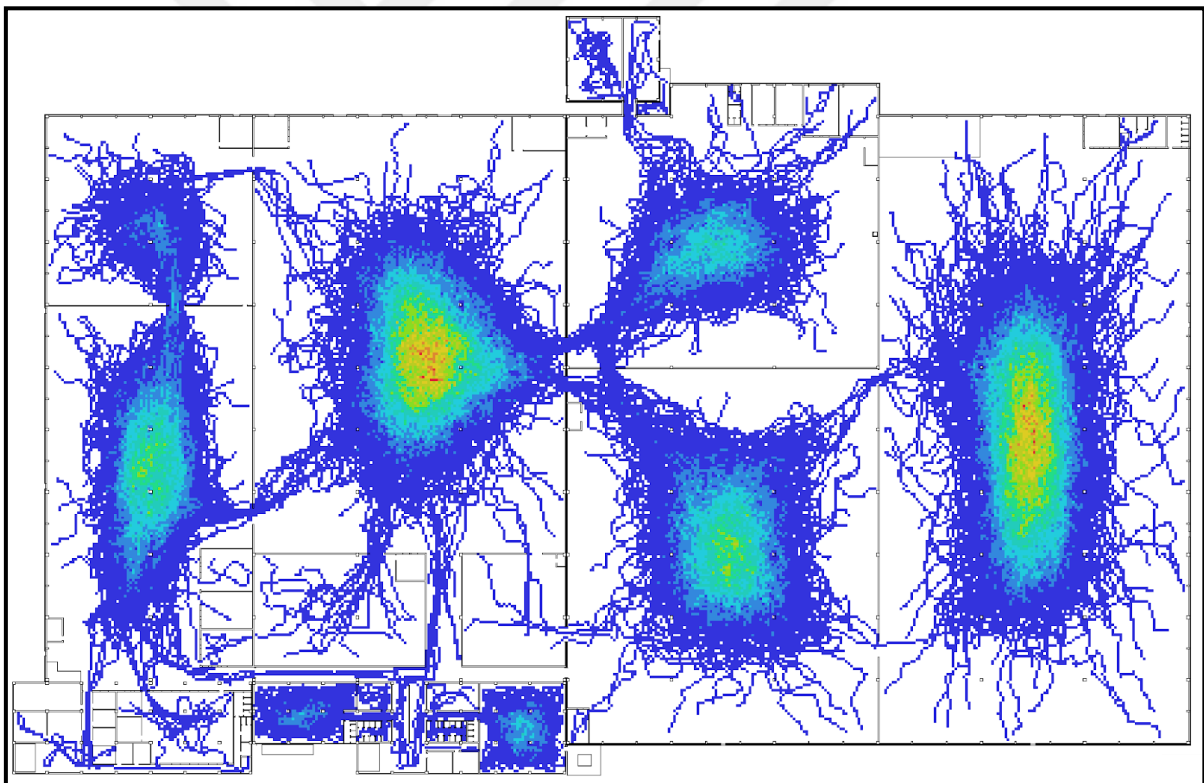


Figure 4.19: Unfurnished Natural Movement Visual Map Analysis of the Factory.

(Adopted and modified by author)

4.2.8 Production Areas Natural Movement Analysis without Furniture

In the natural movement analysis without furniture in the dress sewing area, the visual map shows that there is a flow of movement in the middle of the space. This area serves as an intersection of the flows from other areas that are shaped by their flow paths. However, the color of the map indicates that the density of movement in this area is not significant, as it is mostly represented by light blue color. The lack of furniture in the dress sewing area may have contributed to the lower density of movement, as agents may have less reason to move around without workstations, equipment, or storage areas to access. However, it is also possible that the flow of work and tasks in this area naturally concentrates in the middle, regardless of furniture layout, due to the organization of the production process (Figure 4.19).

In the textile fabric cutting area and textile automatic printing area, similarly to the dress sewing area, there is not much movement flow value and just a density with light blue color in the middle of the area could be observed. This density also is the result of the intersection of the flows from different openings with surrounding areas (Figure 4.19).

4.2.9 Storage Areas Natural Movement Analysis without Furniture

In the natural movement analysis without including furniture, it can be seen that the finished product storage area has a lower value of movement compared to the furnished case. The absence of furniture and equipment in the area provides a more open space, but it also makes the area less attractive for movement. The only visible flow is in the middle of the area, which is shaped by the flow path from the connection opening with the dress sewing area. The color of the area is mostly light blue, which indicates low movement density. The absence of furniture and equipment reduces the complexity and attractiveness of the area for movement, resulting in lower movement values (Figure 4.19).

In the semi-finished storage area and fabric and raw material storage area, the natural movement analysis without including furniture shows that the central part of these areas has a high density of movement flow. The density is indicated by an orange color in the center of these spaces. As the diameter of the circle representing this area increases, the color changes towards blue, indicating a decrease in movement flow density. This density is the

result of the intersection of the flows from different openings with the surrounding areas. These spaces include offices and small storage areas, which contribute to the movement flow in the central area. The natural movement analysis without including furniture shows that the central areas of the semi-finished storage area and fabric and raw material storage area are the most accessible and have the highest density of movement flow (Figure 4.19).

4.2.10 Main Office Area Natural Movement Analysis with Including Furniture

In the furnished version of the natural movement analysis for the main Office area, it can be observed that the density of the right part of the area in the previous case is dispersed to the left part either. The presence of furniture in the area may have influenced the movement of agents, causing them to avoid the right part of the office and move towards the left. But, still, this area has a dark blue color and is an isovist area about movement flow. It shows that there is no movement circulation density by the agents (Figure 4.20).

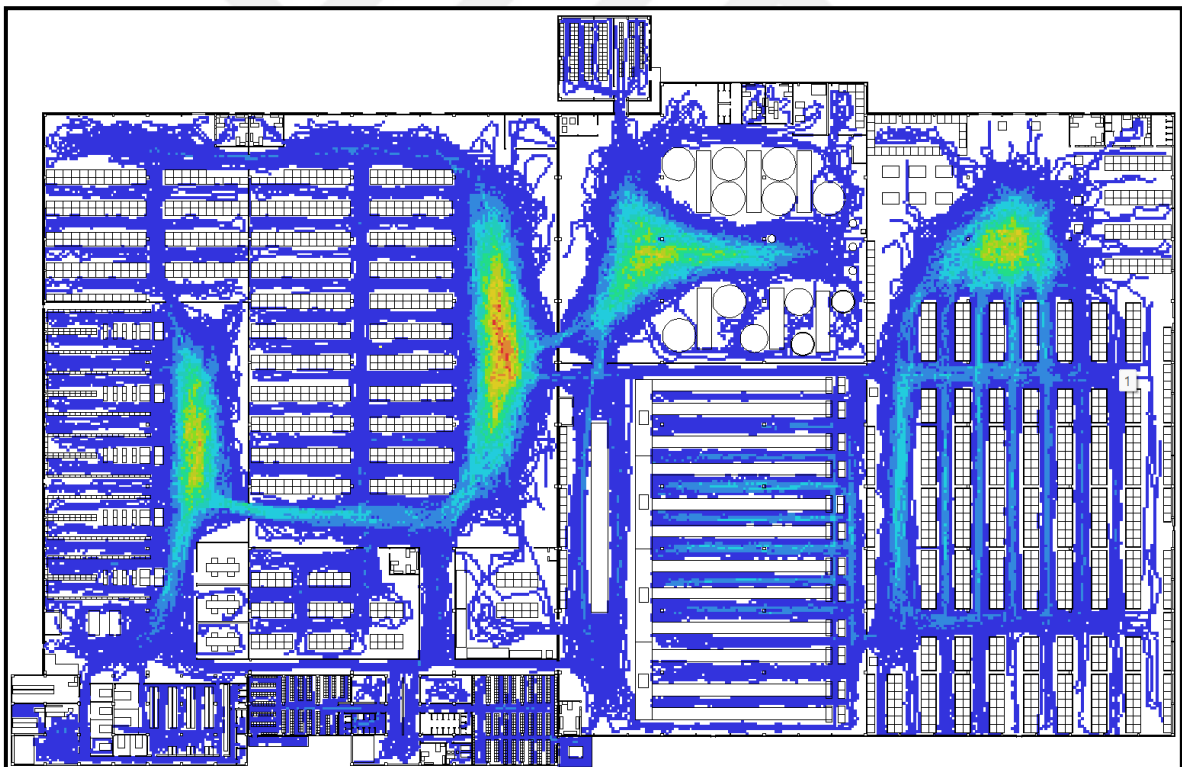


Figure 4.20: Furnished Natural Movement Visual Map Analysis of the Factory.

(Adopted and modified by author)

4.2.11 Production areas Areas Natural Movement Analysis with Including Furniture

The furnished version of the natural movement analysis for the production areas shows that there is a flow density on the right side of the dress sewing area. This density is caused by the intersection of circulation that comes from finished product storage, semi-finished product storage areas, and the main office area. The color in the middle of this spot is orange, indicating the value of movement circulation by agents. The isovist areas in the dress sewing area are located between the sewing tables and other furniture, and they have a dark blue color in the natural movement analysis. This indicates that there is not much movement circulation in these spaces (Figure 4.20).

The fabric cutting area appears to have the most restrictive layout for agent movement. This is due to the presence of a high volume of furniture and machines, which creates a barrier to natural movement circulation through the area. As a result, the area appears as an isovist area with mostly dark blue color. This indicates that agents move relatively freely throughout the area without significant stops or wait times. However, there are some areas between the machines and in the corridors with a light blue color, which suggests a slight density of stops or waits by agents in those particular locations. Overall, the natural movement analysis in the fabric cutting area reveals that the layout and positioning of the furniture and machines have a significant impact on the movement flow of agents within the area (Figure 4.20).

In the furnished version of the natural movement analysis for the textile automatic printing area, the left side to the middle part of the space shows a high density of movement and stops. This volume of density forms a triangle shape due to the intersection of movements that came from the semi-finished Product storage, fabric cutting area, and the chemical material storage on the top of the area. The circulation between the machines also contributes to this density. The color of this area is yellow and green, which shows a high value of movement circulation by agents. In contrast, the other surrounding areas like offices and storage areas have a lower flow density (Figure 4.20).

4.2.12 Storage Areas Natural Movement Analysis with Including Furniture

The finished storage product area seems to have a smooth flow of movement by agents, and there is not much stopping or waiting observed in this area. The dark blue color pattern indicates a low flow density in this area. The cabinets in the main corridor do not create any

significant barriers to movement, and the flow value remains consistent throughout the space. It seems that the agents can easily navigate and move around this area without any significant hindrances or obstructions (Figure 4.20).

The right side of the semi-finished product storage area is characterized by a huge vertical spot with a reddish color in the center. This spot indicates the densest flow intersection in the entire factory, where all the surrounding areas converge. Due to this convergence, agents are more likely to stop in this area, which is also reflected in the higher density of stops. The high flow density is caused by the intersection of movements coming from the fabric cutting area, chemical material storage area, and the top of the textile automatic printing area. Despite the higher density of stops, the flow remains relatively high in this area. It can also be observed that the area on the left side of the space has a lower flow density compared to the right side. This could be due to the placement of the furniture and shelves that create a barrier to the movement flow. The isovist areas between the shelves and other furniture have a dark blue color pattern, indicating that they have a low density of stops and waitings by agents. Moving on to the Accessory storage area and embroidery workshop area, both areas have a similar pattern in terms of natural movement analysis. The density of flow is relatively low, with a dark blue color pattern throughout the space. This could be due to the nature of the activities in these areas, where agents may need to spend more time on specific tasks, resulting in fewer movements. Additionally, the placement of furniture and machines in these areas could also play a role in reducing the flow density (Figure 4.20).

In the Fabric and raw material storage area, there is a density at the top of the area which is related to the loading/unloading area. The corridors shaped by the cabinets in that area have less value of movement flow. But, on the left side of the cabinets that connect with the fabric cutting area, there is a corridor that has a light-blue color that can be considered as a slight movement flow value. Other areas on the top of this space like Office areas do not have any valuable flow movement (Figure 4.20).

5. CONCLUSION

5.1 COMPARISON OF THE VISUAL MAPS IN TERMS OF INCLUDING AND EXCLUDING FURNITURE IN FACTORY SPACES (NITRILE GLOVE FACTORY)

5.1.1 Ground Floor Connectivity Comparison Table

The comparison between the ground floor connectivity analysis with and without furniture shows that furniture and equipment play a significant role in affecting the connectivity and accessibility of different areas in the factory. In the unfurnished case, the visual graph indicates a strong connectivity space in the middle of the factory, while other areas like product warehouse or loading areas and office parts are less connected to each other. However, the visual graph that includes furniture and equipment shows a more distributed pattern of connectivity where furniture acts as physical barriers or enablers of movement and communication between different areas of the factory. The production area remains the most connected space due to its central location, but other areas like the office and warehouse of raw material have improved connectivity with the addition of furniture and equipment. Moreover, the unfurnished case may reveal potential bottlenecks or areas where movement is restricted, while furniture and equipment can facilitate the efficient movement and storage of products.

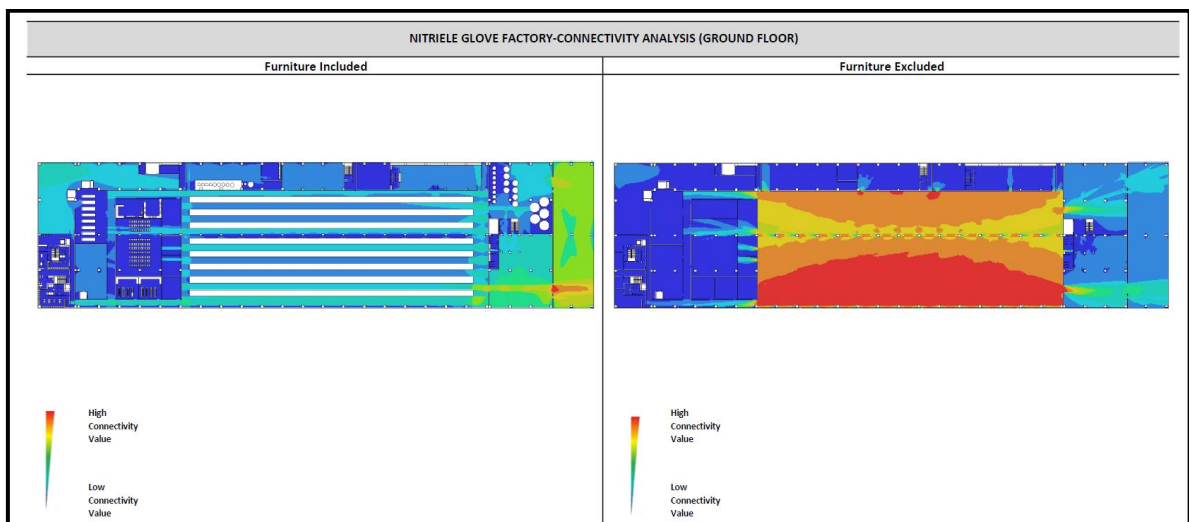


Figure 5.1: Connectivity Comparison Table -Ground Floor.

(Adopted and modified by author)

5.1.2 First Floor Connectivity Comparison Table

The comparison between the first floor connectivity analysis with and without furniture shows that the placement of machinery and equipment has a significant impact on the flow and movement within the space. In the unfurnished version, the production area was the most important area with a strong point of connection, while the office area appeared to be less important. However, the furnished version highlights that the placement of machinery and equipment in the production area separates the dense connectivity that was present in the middle of the area. Nevertheless, connection points still exist at the end of each corridor formed by the machinery. The corridor that connects the production area and the office area is also highlighted as a connection area, with a light blue color indicating a medium degree of connectivity compared to the other parts of the area. The cafeteria region is noted as a central connection area in the office part of the space, indicating the importance of communal spaces and areas of congregation in facilitating movement and interaction within the space. The green color corridor at the bottom of the production area is noted as the main connection path between the office and production areas.

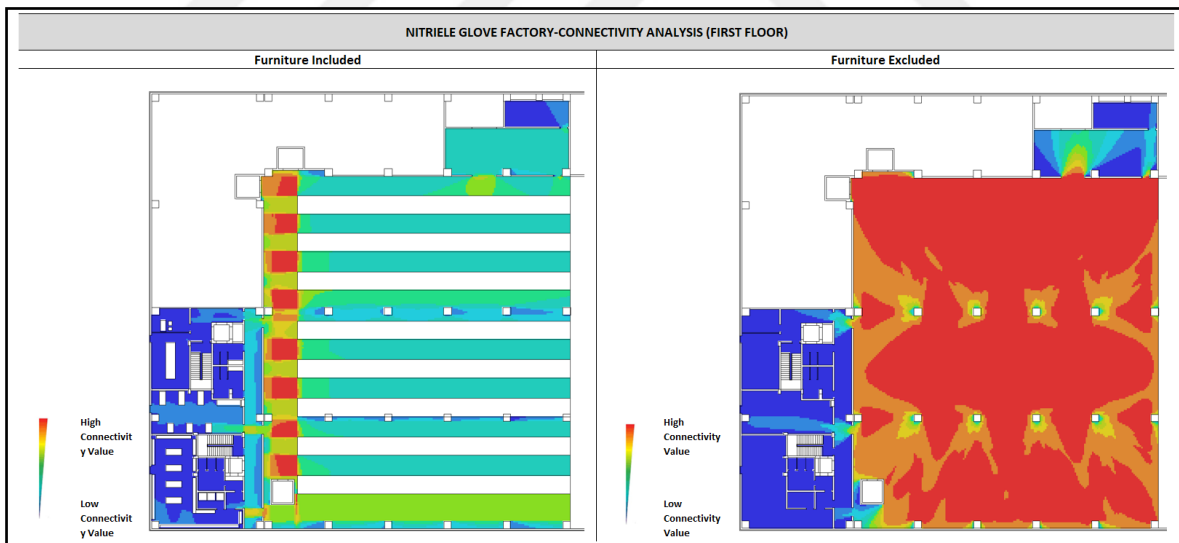


Figure 5.2: Connectivity Comparison Table -First Floor.

(Adopted and modified by author)

5.1.3 Second Floor Connectivity Comparison Table

The analysis of the second floor connectivity without furniture reveals that the entrance to the dining hall is a strong point of connection, while the corridor connecting the dining hall and office parts is a less strong connection area. Smaller corridors and offices also connect other rooms to each other, with different colors highlighting their strength and importance in the overall network.

In contrast, the analysis of the first floor connectivity without furniture highlights the impact of furniture and equipment placement on the overall connectivity pattern of the space. Machinery and equipment placement resulted in a separation of the dense connectivity present in the middle of the production area in the unfurnished version. However, there are still connection points at the end of each corridor formed by the machinery, indicating the significance of careful consideration of these factors in optimizing the layout and organization of the space.

The placement of the corridor connecting the production area and the office area is effective in facilitating movement and flow between the two areas, as indicated by a light blue color. The cafeteria region is also noted as a central connection area in the office part of the space, highlighting the importance of communal spaces and areas of congregation in facilitating movement and interaction within the space. Finally, the green color corridor at the bottom of the production area is noted as the main connection path between the office and production areas, emphasizing the significant impacts of its placement and design on the overall connectivity and efficiency of the space.

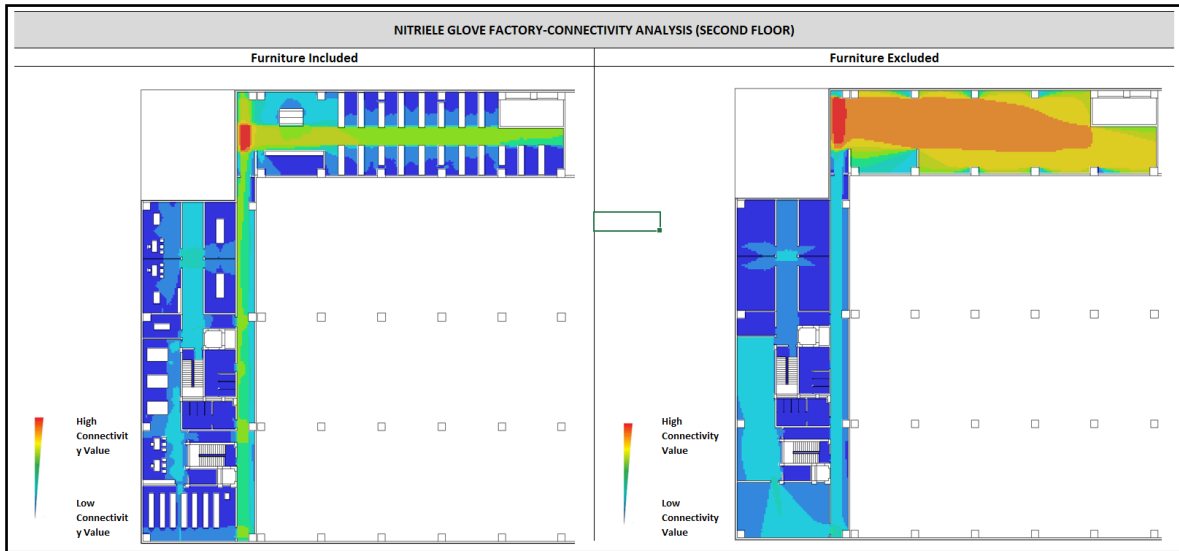


Figure 5.3: Connectivity Comparison Table -Second Floor.

(Adopted and modified by author)

5.1.4 Ground Floor Natural Movement Comparison Table

The comparison analysis between the ground floor natural movement with and without furniture shows that the layout of furniture and other objects has a significant impact on how agents move throughout the space. In the unfurnished case, the production area is the most densely populated part of the floor and the center of the production area is the most connected area. However, agents are less likely to move to other areas of the floor, indicating that the layout of the floor is not optimized for movement between different areas.

In the furnished case, the density of the central part of the factory is spread throughout the entire area due to the machine lines, which act as a barrier for movement circulation and change the way of agent natural movement. The layout of furniture and other objects guides agents to certain areas, and areas that were not originally chosen for movement by agents have changed color from dark blue to green and even yellow in the center of the spaces.

Furthermore, the raw material storage and loading area is a popular area for agents to circulate in both cases, indicating that this area is well-connected and easily accessible. The final product storage and exporting area is also well-optimized for movement and circulation in the furnished case, with a greener appearance than in the unfurnished case.

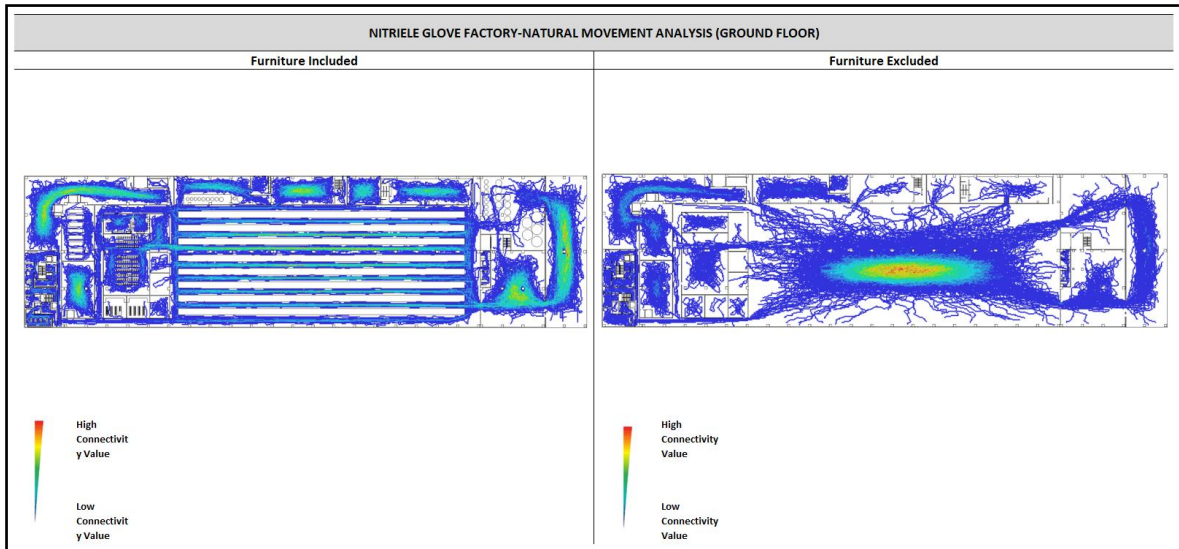


Figure 5.4: Natural Movement Comparison Table -Ground Floor.

(Adopted and modified by author)

5.1.5 First Floor Natural Movement Comparison Table

The comparison between the natural movement analysis without furniture and with furniture reveals some interesting observations. In the first floor natural movement analysis without furniture, the production area is the central point of activity with the highest density of natural movement, while other areas of the factory show low levels of natural movement. The office area has a light blue spot in the middle of the dressing room, which suggests that agents choose to move in that area. On the top floor of the factory, the temporary storage area is displayed as the less preferred area for movement by the agents.

In contrast, the first floor natural movement analysis with furniture shows that in the production area, the movement of agents is primarily concentrated in the corridors that are shaped by the location of production line machines. The main corridor at the start point of the machine is green, indicating that agents tend to choose this path for moving through the production area. The office area shows that the main corridor connecting the production area and the office area is light blue, indicating that agents prefer to use this path for movement. The density of movement in the dressing room area is also spread out due to the presence of a wardrobe acting as a barrier. Moreover, the temporary storage area on the top floor appears to be more crowded with movement, with the central part of the area colored orange.

Overall, the addition of furniture seems to have a significant impact on the movement of agents in the factory. In the production area, the furniture seems to have influenced the pathways taken by agents, with the corridors shaped by the location of production line machines becoming the primary routes. The presence of a wardrobe in the dressing room area also affected the movement of agents, leading to a more spread-out density of movement. Additionally, the temporary storage area on the top floor appears to have become a more preferred area for movement, possibly due to the arrangement of furniture in the area.

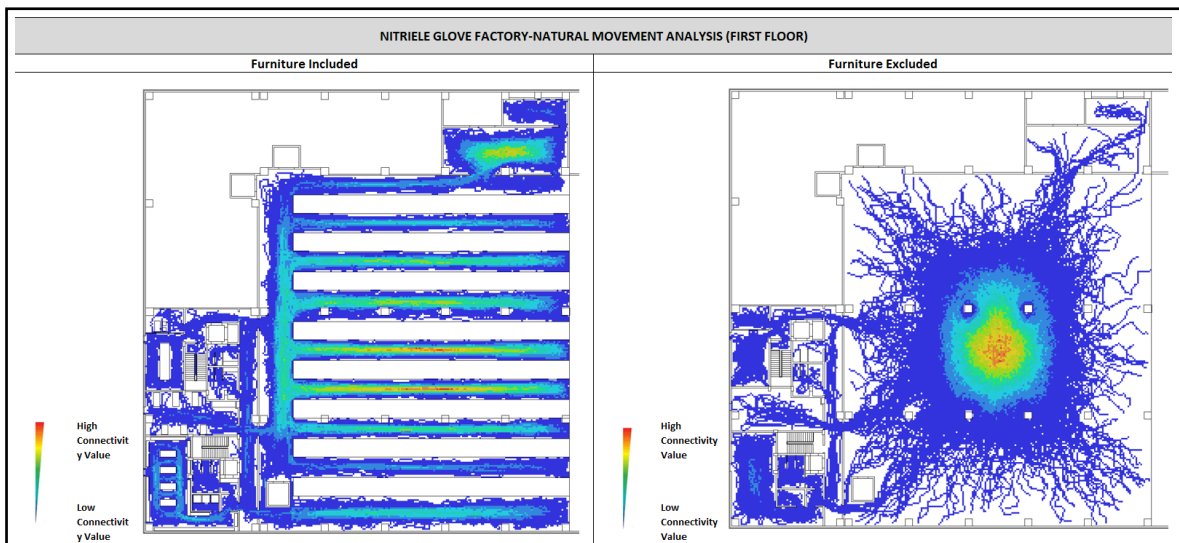


Figure 5.5: Natural Movement Comparison Table -First Floor.

(Adopted and modified by author)

5.1.6 Second Floor Natural Movement Comparison Table

The natural movement analysis of the first floor without furniture indicates that the dining hall is a crowded area where agents tend to converge, likely due to it being a common meeting spot or a pathway for movement. The main corridor is primarily used for efficient movement between the dining hall and office areas, while secondary corridors have intersections where agents frequently cross paths. The office area has popular points of intersection, while other parts are less frequently used for movement.

On the other hand, the analysis with furniture shows that the density in the middle of the dining hall spreads horizontally due to the location of tables, and there are areas that were not scanned in the unfurnished version but are walked through by agents in the furnished

case. The main corridor is an important pathway for agents and used regularly to access different areas of the building, with faster movement indicated by light blue and more relaxed movement indicated by green color. The secondary corridors in the office area are crowded, indicating that they are important pathways, while the training hall and the room connecting the secondary corridor are denser due to the presence of furniture that guides agents to change direction and avoid crowdedness.

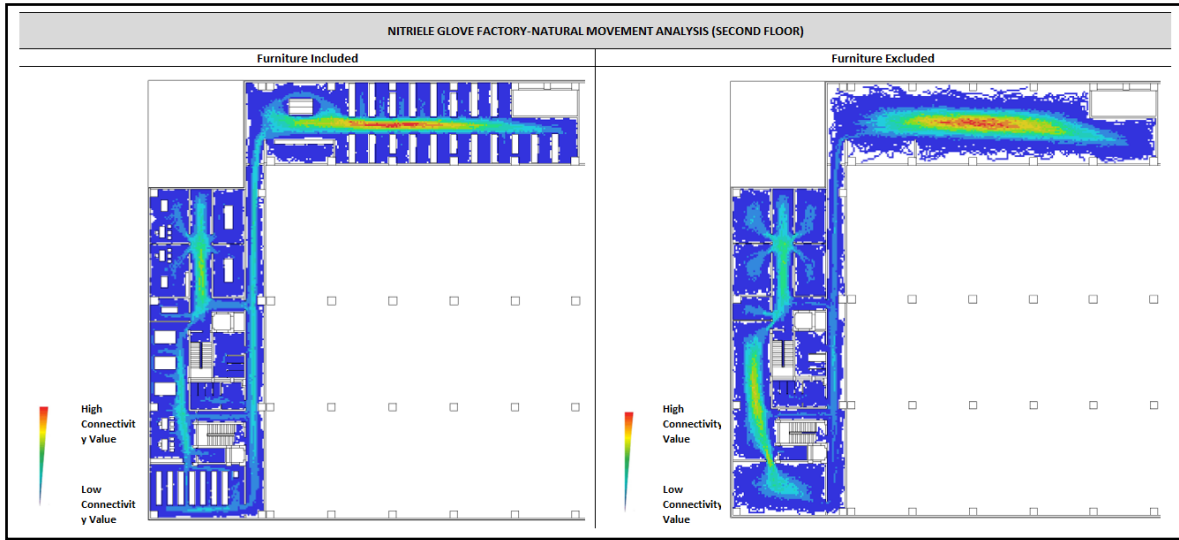


Figure 5.6: Natural Movement Comparison Table -Second Floor.

(Adopted and modified by author)

5.2 COMPARISON OF THE VISUAL MAPS IN TERMS OF INCLUDING AND EXCLUDING FURNITURE IN FACTORY SPACES (TEXTILE PRODUCTION FACTORY)

5.2.1 Connectivity Comparison Table

The comparison between the two analyses, one with furniture excluded and the other with furniture included, shows that the furniture significantly affects the connectivity patterns, flow of movement, and visibility of the production areas. In the analysis that excluded furniture, the office area appeared disconnected or isolated, while the production areas had varying levels of connectivity. The dress sewing and textile automatic printing areas were relatively isolated, while the automatic textile fabric cutting area had many connection paths to other production areas. The finished products storage area was less connected than other

areas of the factory, while the semi-finished product storage area was shown as a relatively strong connectivity point.

In the analysis that included furniture, the main office area had limited visibility and was connected to other areas and corridors by lighter blue connection points. The production areas had changed their connectivity patterns due to furniture, affecting the flow of movement and visibility. For instance, the textile fabric cutting area had furniture and equipment that affected the isovist analysis of the space, while the textile automatic printing area had high connectivity density spots where printing machines were located. The finished product storage area had a unique shape due to the location of cabinets. The Accessory storage area and embroidery workshop area were mostly isovist areas surrounded by cabinets, furniture, and equipment. The furnished version of the fabric and raw material storage area had low connectivity value in the corridors shaped by cabinets.

Therefore, it can be inferred that the furniture and equipment play a significant role in determining the connectivity and spatial configuration of the production areas. With furniture included, the analysis shows how the furniture affects the flow of movement and visibility, as well as the spatial configuration of the storage areas.

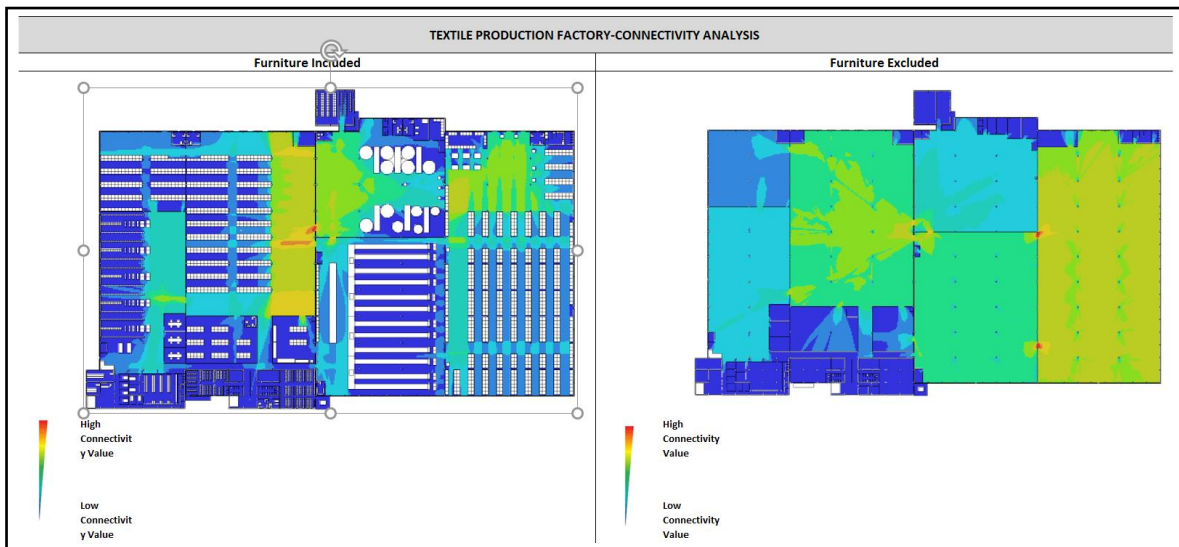


Figure 5.7: Connectivity Comparison Table-Second Floor.

(Adopted and modified by author)

5.2.2 Natural Movement Comparison Table

In the unfurnished analysis of the main office area, it was found that the agents had a reluctance to move towards the right part of the office area. Similarly, in the production areas without furniture, there is not much movement flow value, and just a density with light blue color in the middle of the area could be observed. The lack of furniture in the dress sewing area may have contributed to the lower density of movement. In the storage areas, the absence of furniture and equipment provides a more open space, but it also makes the area less attractive for movement. In contrast, the natural movement analysis with furniture in the main office area shows that the density of the right part of the area in the previous case is dispersed to the left part. The presence of furniture may have influenced the movement of agents, causing them to avoid the right part of the office and move towards the left. In the fabric cutting area, the presence of a high volume of furniture and machines creates a barrier to natural movement circulation through the area.

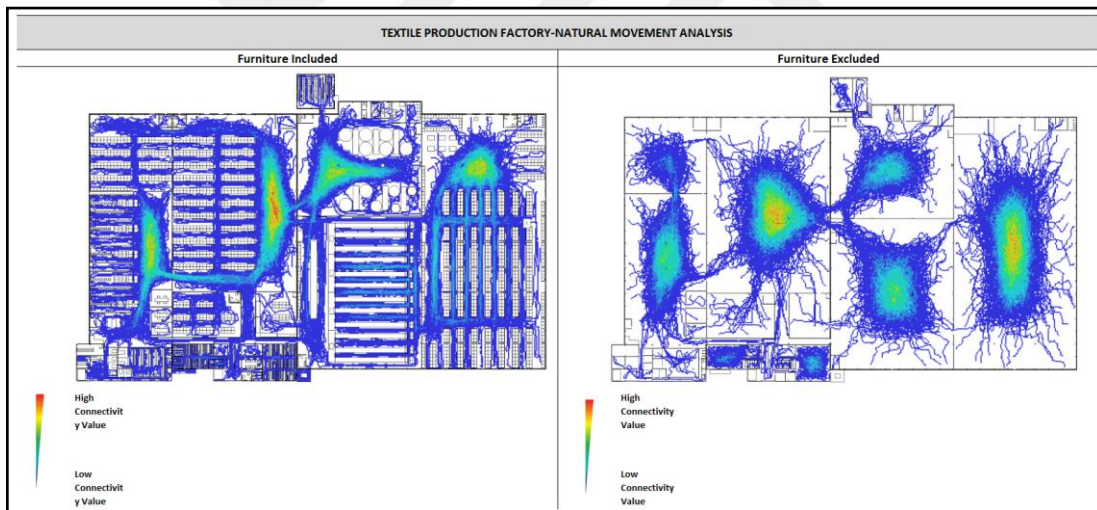


Figure 5.8: Natural Movement Comparison Table-Second Floor.

(Adopted and modified by author)

To sum up, the Space Syntax method has been applied to analyze the natural user movement and connectivity of two industrial building case studies, namely the Nitrile Glove manufacturing factory and the Textile production factory. The analysis was conducted with and without furniture and equipment to evaluate the impact of spatial configuration on user movement and connectivity. In addition to the findings related to natural movement behavior and connectivity points in industrial buildings, this research also sheds light on the importance of considering spatial cognition in industrial building design.

Spatial cognition and circulation are essential in industrial building design, and the findings of this research indicate that the placement of machines, furniture, and spatial configuration significantly affect natural movement behavior and connectivity points in industrial buildings. Spatial cognition refers to how people perceive and navigate through physical spaces. It encompasses factors such as visibility, accessibility, and wayfinding. In the context of industrial buildings, spatial cognition is particularly important because of the complex and often hazardous nature of the activities that take place within these spaces. Workers need to be able to quickly and safely move through the space to perform their tasks, and the spatial layout needs to be designed in a way that supports this. The furnished case studies were found to have more connectivity and natural movement, indicating the importance of considering furniture and equipment placement in industrial building design.

By using the Depthmap X software, visibility graphs were created to represent direct and indirect lines of sight between different locations within the spaces. The results were analyzed using logical reasoning, and it was found that the furniture's placement significantly impacts connectivity and natural movement behavior. Specifically, the placement of machines and equipment affected the connectivity points and spaces in the buildings, while spatial configuration impacted natural user movement behavior.

Therefore, it is crucial to consider furniture and equipment placement in industrial building design to enhance the connectivity and natural movement behavior in these types of buildings. Additionally, the findings of this research can be used to integrate spaces in industrial buildings and improve their design to provide a more efficient and effective work environment.

As a result, this research demonstrated the importance of the Space Syntax method in analyzing natural user movement and connectivity in industrial building design. The space syntax method used offers a valuable tool for analyzing spatial cognition in industrial buildings. By generating visual maps and tables, the method allows designers and planners to better understand how the spatial configuration of a building can impact movement behavior and connectivity. This can lead to more informed design decisions that better support the needs of workers and improve safety and efficiency in industrial building spaces.



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