

## Building Environments for Female Sex Trafficking Victims: A Parametric Design Approach

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*This paper presents findings on the use of computational design techniques to analyse and develop a building environment based on a set of defined design principles. In this study, we explored and established the design principles of a building environment for female victims of sex trafficking that contribute to the overall recovery and reintegration of these women into society. Additionally, we examined and evaluated the use of parametric design as a computational tool to support the development of a model for designing these building environments. We address this issue by creating a set of guidelines based on data research and literature review and testing data-driven techniques, including generative design and models for self-organising floor plans. The paper explores the benefits as well as the potential disadvantages of such design approaches by comparing them to this set of desired guidelines. Finally, we present preliminary findings from this analysis and suggest further research directions.*

### Introduction

As an urban typology, a building environment for sex trafficking victims is not clearly defined, nor sufficiently studied. They are usually considered a subset of healthcare settings, sheltering or temporary accommodations. Additionally, due to the severe conditions imposed on sex trafficking victims, which can last anywhere from a few days to several years, each survivor requires greater emotional support and care. If the victims are not treated appropriately, they might develop a variety of mental disorders<sup>1</sup>. As such, it's crucial to ensure that the design of the accommodation in which they will be housed supports their recovery and healing process, while also supporting their needs.

This research has two aims:

1. to analyse how the built environment can play a critical role in the recovery process of female victims of sex trafficking. This study examined how a building environment, with its design and taking into account all the relevant parameters and stakeholders, may help these women to recover and set the groundwork for their independent return to society.
2. to explore and examine the potential value of parametric design as a computational tool for developing the spatial configurations of a building

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1. Idris, I. (2017) *Interventions to support victims of modern slavery* [Online] December 2017. Available at: <https://assets.publishing.service.gov.uk/media/5a5f213de5274a443e00370e/256-Interventions-to-support-victims-of-modern-slavery.pdf> [Accessed: 18th December 2019]

environment for female sex trafficking victims based on specific parameters that will allow a deeper exploration of design options.

This study proposes a novel approach to the design of building environments based on the physiological and psychological needs of sex trafficking victims and the way to facilitate their access to a range of services that will contribute to their empowerment.

In this research, a parametric design method was used to develop a building environment for female victims of sex trafficking. Using a computational model that could lead to deeper design exploration, this research aims to design the built environment based on specific design principles that can play a critical role in the recovery process of these women. By analysing their unique design and considering relevant parameters and stakeholders, this study investigated how the building environment could help these women recover and set the groundwork for their independent return to society. The process involved the exploration and critical examination of two algorithms, using as parameters the design principles for developing a building environment for female victims of sex trafficking: the Squarified Treemap and the Magnetising Floor plan Generator. The software used in this project was Rhinoceros for the modelling and Grasshopper for the visual coding.

## Literature Review

### Human Trafficking

Human trafficking is a 'multi-billion-dollar form of international organised crime, constituting modern-day slavery'.<sup>2</sup> An average of 150 billion dollars is produced each year by exploiting vulnerable people's bodies and forcing them to work against their will. There are various types of human trafficking: sex trafficking, forced labour, bonded labour, involuntary domestic servitude and child soldiers.<sup>3</sup>

Globally, vulnerable people are abused and exploited for their labour and bodies without consent and the number of trafficked people today is estimated at around 40.3 million, the highest in history; an estimated 5.4 out of every 1,000 people are enslaved globally: 71% are women, 29% are men, and 25% are children.<sup>4</sup> The bibliography presents various studies<sup>5 6 7</sup> for domestic abuse

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2. Interpol (2019). *Human trafficking*. [Online] Available at: <https://www.interpol.int/Crimes/Human-trafficking> [Accessed: 3rd June 2020]

3. A21 (2022). *Human Trafficking*. [Online] Available at: <https://www.a21.org/content/human-trafficking/gqe0rc> [Accessed: 21st March 2022]

4. A21 (2022). *Human Trafficking*. [Online] Available at: <https://www.a21.org/content/human-trafficking/gqe0rc> [Accessed: 21st March 2022]

5. BC Housing (2017). *Shelter Design Guidelines*, [Online] Available at: <https://www.bc.housing.org/publications/Shelter-Design-Guidelines.pdf> [Accessed: 15 October 2020]

6. Prestwood, LE (2010). *Architectural design factors of domestic violence shelters that affect outcomes for female domestic violence victims: a naturalistic inquiry to establish grounded theory*

victims and homelessness guidelines but, significantly, there are no specific design instructions for the accommodation of victims of sex trafficking.

A person's vulnerability could occur due to various factors:<sup>8</sup>

- Lack of ability to protect oneself
- Lack of social or family support
- Social exclusion
- Abuse history
- Immigration or refugee status
- Dysfunctional family
- Globalisation
- Political disruption
- War
- Poverty conditions

The reduction of the victims' defensive mechanisms due to these factors is the reason that makes people more vulnerable to trafficking and exploitation. Furthermore, unless the trauma caused by these traumatic events, as well as the factors that contributed to the victims' vulnerability, are addressed, a trafficked victim's chances of being exploited and victimised again are substantial. Re-victimisation can only be avoided by providing specialised support and empowering victims, which will lead to their recuperation and independence.<sup>9</sup>

Various organisations around the world provide support to victims of human trafficking globally. In the UK in particular, the Adult Human Trafficking Victim Care and Coordination contract, funded by the Home Office and the Ministry of Justice, had been assigned to the Salvation Army in England and Wales since July 2011; in January 2021, it was renewed and extended as The Modern Slavery Victim Care and Coordination Contract (MSVCC)<sup>10</sup>. In collaboration with several subcontractors, The Salvation Army supervises the management and oversight of the assistance measures provided to adult victims of human trafficking, evaluating each case independently to provide appropriate support.

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*for future research.* A thesis Submitted to the Office of Graduate Studies of Texas A&M University in partial fulfillment of the requirements for the Degree of Doctor of Philosophy. Texas, US: Texas A&M University. Available from: <https://core.ac.uk/download/pdf/147140403.pdf> [Accessed: 3rd July 2020]

7. Grieder, M.A. & Chanmugam, A. (2013). Applying Environmental Psychology in the Design of Domestic Violence Shelters. *Journal of Aggression, Maltreatment & Trauma*, [Online] 22(4). pp.365-378. Available from: DOI: 10.1080/10926771.2013.775984 [Accessed: 18th October 2019]

8. American Psychological Association (2017) *Facts About Trafficking of Women and Girls*, [Online] Available at: <https://www.apa.org/advocacy/interpersonal-violence/trafficking-women-girls> [Accessed: 11th June 2020]

9. A21 (2022). *Human Trafficking*. [Online] Available at: <https://www.a21.org/content/human-trafficking/gqe0rc> [Accessed: 21st March 2022]

10. The Salvation Army (2022). *New 2021 Victim Care Contract*. [Online] Available at: <https://www.salvationarmy.org.uk/modern-slavery/new-victim-care-contract> [Accessed: 21st March 2022]

Individuals who have been identified as potential victims by the National Referral Mechanism (NRM), a process for identifying potential victims of trafficking, are eligible to have a minimum of forty-five days of support in England, Wales and Northern Ireland (ninety days in Scotland) and can have access to:

- Safe accommodation
- Practical help and advice
- Interpretation and translation services
- Financial support
- Healthcare to meet physical, emotional and mental health needs
- Specialist legal advice
- Education for school-aged dependent children
- Transport to important appointments
- Future-planning support<sup>10 11</sup>

These services are designed to address the emergency, short-term and long-term needs of victims that have been identified by several studies<sup>12 13 14</sup> including safety, food, clothing, medical treatment, translation, counselling, education etc. (Table 1).

The aid provided by NRM is essential for the victims' rehabilitation and integration into society; ultimately, it will enable survivors to overcome their traumatic experiences and move on to the next phase of their recovery. This may include relocating to private residences or subsidised accommodation, as well as returning to their country of origin.<sup>15 16 17 18 19</sup> In contrast, victims who do not receive support are more likely to be exploited and trafficked again.<sup>14</sup>

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11. Hibiscus Initiatives (2020). *Closed doors* [Online]. Available at: [https://hibiscusinitiatives.org.uk/wp-content/uploads/2020/12/2020\\_11\\_24-HI\\_Closed-Doors\\_Main-Report\\_FINAL\\_DIGITAL.pdf](https://hibiscusinitiatives.org.uk/wp-content/uploads/2020/12/2020_11_24-HI_Closed-Doors_Main-Report_FINAL_DIGITAL.pdf) [Accessed: 23rd March 2022]

12. Clawson H. J. & Dutch, N. (2008). *Addressing the needs of victims of human trafficking: challenges, barriers, and promising practices*. [Online] July 2008. Available at: <https://aspe.hhs.gov/report/addressing-needs-victims-human-trafficking-challenges-barriers-and-promising-practices> [Accessed: 18th December 2019]

13. Purple Teardrop Campaign (2012). *Support Safehouses for Trafficking Victims*. [Online] Available at: <http://www.purpleteardrop.org.uk/what-we-do/support-safehouses-for-trafficking-victims/> [Accessed: 18th December 2019]

14. Idris, I. (2017) *Interventions to support victims of modern slavery* [Online] December 2017. Available at: <https://assets.publishing.service.gov.uk/media/5a5f213de5274a443e00370e/256-Interventions-to-support-victims-of-modern-slavery.pdf> [Accessed: 18th December 2019]

15. UN Human Rights Committee (2020). *Joint civil society report on trafficking and modern slavery in the UK to the UN Human Rights Committee*, [Online] Available at: <https://www.antislavery.org/wp-content/uploads/2020/01/Submission-HRC-modern-slavery-in-UK-Jan20.pdf> [Accessed: 12th June 2020]

16. UK. Department of Justice (2013) *Human Trafficking Know Your Rights*. Available from: <https://www.justice-ni.gov.uk/sites/default/files/publications/doj/ht-leaflet-english.pdf> [Accessed: 12th June 2020]

17. Human Trafficking Foundation (2020). *Improving Victim Support*. [Online] Available at: <https://www.humantraffickingfoundation.org/policy> [Accessed: 12th June 2020]

**Table 1.** Needs of Victims of Human Trafficking

	International		Domestic Minors
	Adults	Minors	
Emergency			
Safety	•	•	•
Housing	•	•	•
Food / Clothing	•	•	•
Translation	•	•	
Legal guardianship		•	•
Short / long term			
Transitional housing	•		•
Long-term housing	•		•
Permanency placement		•	
Legal assistance	•	•	•
Advocacy			
Translation	•	•	•
Medical care	•	•	•
Mental health / Counselling	•	•	•
Substance abuse treatment			•*
Transportation	•		•
Life skills	•	•	•
Education	•	•	•
Financial assistance / management	•		•
Job training / Employment	•	•	•
Childcare	•	•	•
Reunification / Repatriation	•	•	•

\*While substance abuse treatment may be a need for international victims, it was only identified as a need for domestic minor victims

Source: Clawson and Dutch (2008).

## Key Statistics

According to the "Year eight report on The Salvation Army's Victim Care and Coordination Contract", The Salvation Army provided support to survivors of modern slavery in ninety-nine different countries from July 2018 to June 2019. Approximately 2,251 potential victims accessed the service to receive support (a 21% increase from the previous year). A total of 1,247 identify as women, 999 identify as men, and 5 identify as transgender. There were 881 cases of trafficking for sexual exploitation recorded (Table 2). About one-quarter of the survivors assisted were Albanians, with 95% being female victims of sex trafficking.

18. The Salvation Army (2019b). *62% Rise In Human Trafficking Victims Seeking Support*, [Online] Available at: <https://www.salvationarmy.org.uk/news/62-rise-human-trafficking-victims-seeking-support> [Accessed: 12th June 2020]

19. GOV.UK (2020). *National referral mechanism guidance: adult (England and Wales)*. [Online] Available at: <https://www.gov.uk/government/publications/human-trafficking-victims-referral-and-assessment-forms/guidance-on-the-national-referral-mechanism-for-potential-adult-victims-of-modern-slavery-england-and-wales> [Accessed: 19th January 2021]

Among the 2,251 potential victims who accessed support, 46% came from London. The average number of days spent in safe houses was 159<sup>20</sup> (Table 3).

**Table 2.** *Exploitation Types by Gender*

Exploitation type	Female	Male	Trangender	Total
Domestic Servitude	227	47	0	274
Labour	150	922	0	1072
Organ removal	1	0	0	1
Sexual	855	21	5	881
To be confirmed	14	9	0	23
Total	1247	999	5	2251

Source: The Salvation Army (2019a).

**Table 3.** *Length of Time in Support*

	Accommodation in safe house	Outreach support
Average (mean) days in service	159	508

Source: The Salvation Army (2019a).

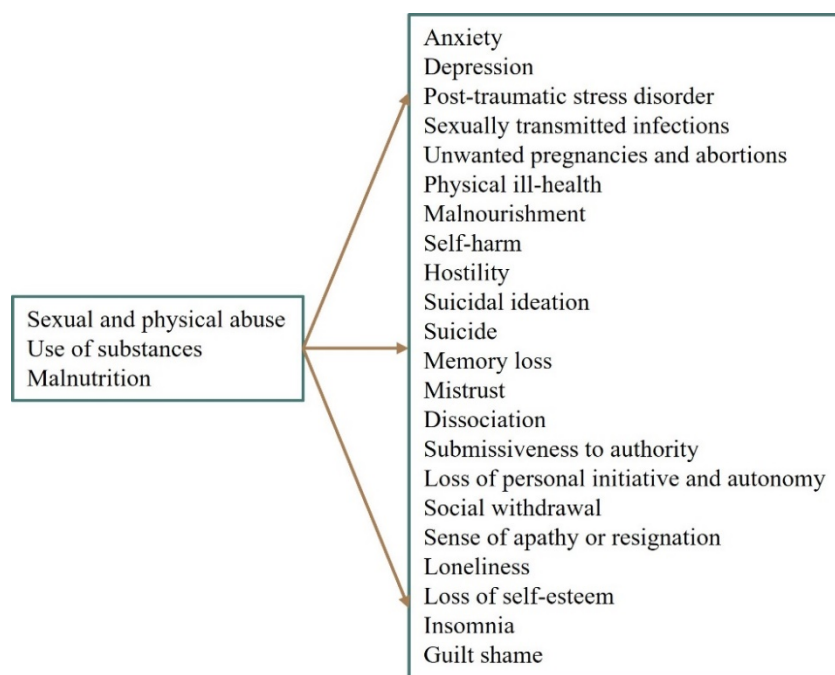
## Female Sex Trafficking

The focus of this research is on the accommodation provided to female victims of sex trafficking. For victims of trafficking and exploitation, shelter is crucial since homelessness and unsafe housing can lead to re-exploitation and re-victimization by both new and existing offenders. Female sex trafficking is a global phenomenon that occurs in every country, 'either as a source, transit or destination area'.<sup>21</sup> Women from developing countries or dysfunctional groups in developed countries are captured by an organised network of traffickers, misled by the hope of a better life. Isolated by their traffickers in a strange environment they are subjected to constant sexual exploitation, terrorism and inhumane conditions<sup>21</sup>. During their captivity, these women experience sexual and physical violence, drug use and malnutrition.<sup>22</sup>

20. The Salvation Army (2019a). *Supporting victims of modern slavery*, [Online] Available at: <https://www.salvationarmy.org.uk/sites/default/files/resources/2020-03/FINAL%20Modern%20Day%20Slavery%20Report%202019%20Colour.pdf> [Accessed: 10th June 2020]

21. Interpol (2022). *Types of human trafficking*. [Online] Available at: <https://www.interpol.int/Crimes/Human-trafficking/Types-of-human-trafficking> [Accessed: 21st March 2022]

22. A21 (2022). *Human Trafficking*. [Online] Available at: <https://www.a21.org/content/human-trafficking/gqe0rc> [Accessed: 21st March 2022]



**Figure 1.** *Mental Health Issues of Victims of Sex Trafficking*

Source: Papadopoulou 2021.

Data: A21(2022), Idris (2017) and Hodge (2014)

Domestic homicide, domestic abuse, sexual assault, child abuse, female genital mutilation (FGM), forced marriage, and harassment in work and public life are all examples of violence against women.<sup>23</sup> They are, however, all distinct from the crime of sex trafficking and highlight the fact that victims of sex trafficking face some of the most complex mental health challenges of any criminal victim.<sup>24</sup> However, there are similarities in the emotional impact on women and the mental disorders that result from both sorts of crimes. For example, between 2017 to 2020, an estimated 63 per cent of women aged 16 and above who were victims of relevant crimes such as assault and rape in all forms experienced mental or emotional issues, and 10% attempted suicide.<sup>25</sup> These mental issues are much more significant in victims of sex trafficking; according to the University of Liverpool, sex trafficking victims require greater emotional treatment in the first

23. Office for National Statistics (2022). *The lasting impact of violence against women and girls* [Online] November 2021. Available at: [https://www.ons.gov.uk/peoplepopulationandcommunity/crimeandjustice/articles/thelastingimpactofviolenceagainstwomenandgirls/2021-11-24#:~:text=Violence%20against%20women%20and%20girls%20\(VAWG\)%20is%20an%20umbrella%20term,in%20work%20and%20public%20life](https://www.ons.gov.uk/peoplepopulationandcommunity/crimeandjustice/articles/thelastingimpactofviolenceagainstwomenandgirls/2021-11-24#:~:text=Violence%20against%20women%20and%20girls%20(VAWG)%20is%20an%20umbrella%20term,in%20work%20and%20public%20life) [Accessed: 22nd March 2022]

24. Kaylor, L. (2015). Psychological impact of human trafficking and sex slavery worldwide: Empowerment and intervention. *Intern from John Jay College of Criminal Justice New York, NY*. [Online] Available at: [https://scholar.googleusercontent.com/scholar?q=cache:KOVx4XHvtSAJ:scholar.google.com/+Kaylor,+2015&hl=en&as\\_sdt=0,5](https://scholar.googleusercontent.com/scholar?q=cache:KOVx4XHvtSAJ:scholar.google.com/+Kaylor,+2015&hl=en&as_sdt=0,5) [Accessed: 21st March 2022]

25. Office for National Statistics (2022). *The lasting impact of violence against women and girls* [Online] November 2021. Available at: [https://www.ons.gov.uk/peoplepopulationandcommunity/crimeandjustice/articles/thelastingimpactofviolenceagainstwomenandgirls/2021-11-24#:~:text=Violence%20against%20women%20and%20girls%20\(VAWG\)%20is%20an%20umbrella%20term,in%20work%20and%20public%20life](https://www.ons.gov.uk/peoplepopulationandcommunity/crimeandjustice/articles/thelastingimpactofviolenceagainstwomenandgirls/2021-11-24#:~:text=Violence%20against%20women%20and%20girls%20(VAWG)%20is%20an%20umbrella%20term,in%20work%20and%20public%20life) [Accessed: 22nd March 2022]

evaluation stage than victims of other types of trafficking.<sup>26</sup> Moreover, the variety of mental disorders individuals experience as a result of the traumatic situations they were exposed to, such as anxiety, depression, self-harm, social disengagement, and so on (Figure 1), could persist for a long time. It is, therefore, essential to ensure that these individuals are placed in a building environment that will address their practical needs as well as facilitate their rehabilitation.

### What is needed

Current solutions for building environments for sex trafficking victims primarily focus on providing survivors with safe accommodation.<sup>27</sup> These houses serve as places where residents' fundamental physiological needs are met and where they can access a variety of services to address those needs. However, three gaps have been identified in this study:

- Gap in the existing literature  
The specific gap resides in the lack of relevant literature, bibliography, and specialized study on the interior architecture and design of a building environment for female sex trafficking victims.
- Gap in the interior design standards and guidelines  
This specific gap relates to the lack of interior design guidelines and standards that should be adhered to ensure the effective development of a building environment for female sex trafficking victims.
- Gap in the usage of machine learning  
The specific gap focuses on the lack of application of advanced analytical and design models for such environments. Such architectural studies could reflect the specific needs of sex-trafficked women towards their recovery and gradual reintegration into society.

### Research Methodology

This project aims to investigate and identify the design principles of a building environment for female sex trafficking victims that contribute to their overall healing and reintegration into society. Furthermore, it also aims to investigate how parametric design may be utilised to develop a model of a therapeutic environment that can aid in the healing process of its patients. By analysing primary and secondary data, we identified the key needs of the victims

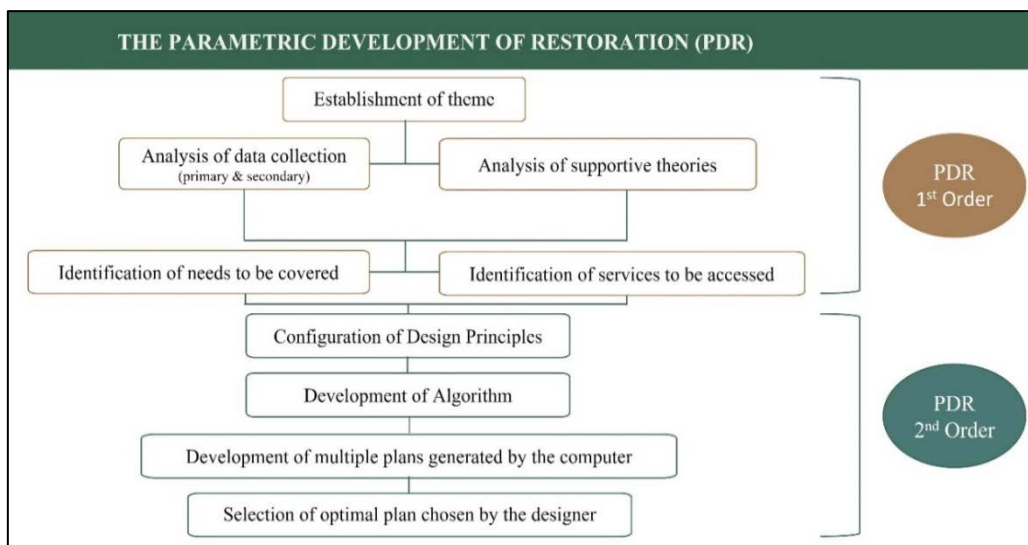
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26. Idris, I. (2017) *Interventions to support victims of modern slavery* [Online] December 2017. Available at: <https://assets.publishing.service.gov.uk/media/5a5f213de5274a443e00370e/256-Interventions-to-support-victims-of-modern-slavery.pdf> [Accessed: 18th December 2019]

27. Human Trafficking Foundation (2018). *The Slavery and Trafficking Survivor Care Standards* [Online] October 2018. Available at: <https://www.antislaverycommissioner.co.uk/media/1235/slavery-and-trafficking-survivor-care-standards.pdf> [Accessed: 21st March 2022]



and the services that they should receive to facilitate their recovery. Through the use of interviews (analysed qualitatively) and secondary research data, the design principles of a building environment for female sex trafficking victims were established. These were set as parameters to specific data-driven techniques, including generative design and models for self-organising floor plans that were critically examined. Following this critical examination, the most appropriate technique was selected according to the research criteria. Several spatial solutions were generated and the optimal one according to the design principles and requirements was selected. This process led to the development of the Parametric Development of Restoration (PDR) model (Figure 2).



**Figure 2.** *The Parametric Development of Restoration*

Source: Papadopoulou 2021.

### Elaboration of Design Criteria

This study is focused on two main objectives:

- Objective 1: To describe how the design of the building environment will meet the physiological and psychological needs of the women, contributing positively to their healing.
- Objective 2: To examine how the design of the building environment can facilitate the access of women to a range of services that will allow them to take control of their lives.

## Objective 1

Numerous studies<sup>28 29 30 31 32 33 34</sup> have been conducted over the years to investigate the relationship between the characteristics of a built environment and the well-being of its residents; from the Classical Greece era to the present day, the perception of the built environment's impact on human well-being as well as the healing process of patients has been extensively researched.

In his Theory of Supportive Design, Ulrich (2001)<sup>35</sup> discusses the impact of stress on patients, and how building environments that are designed to relieve stress are beneficial to patients' healing and recuperation. Three evidence-based design guidelines are identified in his analysis as having a positive impact on patients' stress and healing outcomes in therapeutic settings. These are:

### 1. Foster a Sense of Control

Control, or an individual's ability to influence environmental conditions, is directly related to stress and health outcomes. In a therapeutic setting, a lack of privacy, excessive noise, poor lighting, or spatial disorientation can all contribute to a loss of control. Selecting from a variety of building features can benefit the well-being of patients and the satisfaction of staff.

### 2. Promote Social Support

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28. Ulrich, RS (2001) 'Effects of Healthcare Environmental Design on Medical Outcomes'. In *Design and Health: Proceedings of the Second International Conference on Health and Design* [Online] 49.pp. 59. Available from: [https://www.researchgate.net/publication/273354344\\_Effects\\_of\\_Healthcare\\_Environmental\\_Design\\_on\\_Medical\\_Outcomes](https://www.researchgate.net/publication/273354344_Effects_of_Healthcare_Environmental_Design_on_Medical_Outcomes) [Accessed: 7th December 2020]

29. Dellinger, B. (2010) Healing Environments. In: McCullough, C. (ed.). *Evidence-based Design for healthcare facilities*. [Online] Indianapolis: Renee Wilmeth. Available from: <http://docshare02.docshare.tips/files/7358/73586537.pdf> [Accessed: 7th December 2020]

30. Huisman, E.R.C.M., Morales, E., Van Hoof, J. and Kort, H.S.M. (2012) 'Healing environment: A review of the impact of physical environmental factors on users'. *Building and Environment* [Online] 58. pp.70-80. Available from: <https://doi.org/10.1016/j.buildenv.2012.06.016> [Accessed: 23rd November 2020]

31. Codinhoto, R. Tzortzopoulos, P., Kagioglou, M., Aouad, G. and Cooper, R. (2009) 'The impacts of the built environment on health outcomes'. *Facilities* [Online] 27 (3/4). pp.138-151. Available at: <https://doi.org/10.1108/02632770910933152> [Accessed: 8th December 2020]

32. Schweitzer, M., Gilpin, L. & Frampton, S. (2004) 'Healing Spaces: Elements of Environmental Design That Make an Impact on Health'. *The Journal of Alternative and Complementary Medicine* [Online]10 (1). pp.71-83. Available at: <https://doi.org/10.1089/acm.2004.10.S-71> [Accessed: 24th November 2020]

33. Day, C. (2004). *Places of the Soul - Architecture and Environmental Design as a Healing Art* [Online] Oxford: Elsevier. Available from: [https://www.academia.edu/37164088/Places\\_of\\_the\\_Soul\\_Architecture\\_and\\_Environmental\\_Design\\_as\\_a\\_Healing\\_Art](https://www.academia.edu/37164088/Places_of_the_Soul_Architecture_and_Environmental_Design_as_a_Healing_Art) [Accessed: 30th June 2020]

34. Grieder, M.A. & Chanmugam, A. (2013). Applying Environmental Psychology in the Design of Domestic Violence Shelters. *Journal of Aggression, Maltreatment &Trauma*, [Online] 22(4). pp.365-378. Available from: DOI: 10.1080/10926771.2013.775984 [Accessed: 18th October 2019]

35. Ulrich, RS (2001) 'Effects of Healthcare Environmental Design on Medical Outcomes'. In *Design and Health: Proceedings of the Second International Conference on Health and Design* [Online] 49.pp. 59. Available from: [https://www.researchgate.net/publication/273354344\\_Effects\\_of\\_Healthcare\\_Environmental\\_Design\\_on\\_Medical\\_Outcomes](https://www.researchgate.net/publication/273354344_Effects_of_Healthcare_Environmental_Design_on_Medical_Outcomes) [Accessed: 7th December 2020]

In a healthcare facility whose design supports access to physical and emotional support from both their families and healthcare professionals, stress can be reduced and health outcomes may be enhanced.

### 3. Provide access to Nature and other Positive Distractions

Research has demonstrated that exposure to natural views or access to nature can reduce patients' feelings of stress and positively impact their psychological well-being.

Similarly, Dellinger (2010)<sup>36</sup> suggests specific design interventions that can improve the treatment experience by addressing the five senses: sound, touch, sight, smell and taste. These interventions have a positive impact on patients' stress and discomfort in a therapeutic environment:

- Sound stress reduction: Utilizing sound-absorbing materials and separating employee areas can reduce sound stress, as can providing music, placing water fountains, etc.
- Touch stress reduction: Using soft fabrics and natural materials can reduce touch stress.
- Sight stress reduction: Reducing stress through sight is achieved by ensuring clean and uncluttered areas, using coordinated colours and materials, displaying art, and providing means for easy orientation and navigation.
- Smell stress reduction: Reducing stress by filtering the air and using environmentally friendly cleaning products.
- Taste stress reduction: Offering a variety of nutritious and tasty meals throughout the day can reduce taste stress.

The role human senses play in the way people perceive the surrounding environment is also analysed in the Theory of Embodiment. The Theory of Embodiment indicates that the human perception of the surroundings is not solely based on the brain but is shaped by the merge of the entire body and mind as a single entity and as a link with the notion of reality. As stated in this theory, a person's connection to space and how they relate to their environment can be attributed to issues of embodiment.<sup>37 38</sup> By utilizing the surrounding environment as a tool, our senses shape our perception of reality. This perception impacts how

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36. Dellinger, B. (2010) Healing Environments. In: McCullough, C. (ed.). *Evidence-based Design for healthcare facilities*. [Online] Indianapolis: Renee Wilmeth. Available from: <http://docshare02.docshare.tips/files/7358/73586537.pdf> [Accessed: 7th December 2020]

37. Merleau-Ponty, M. (2006). *Phenomenology of perception*. (C. Smith, Trans.). London: Routledge Classics (Original work published 1945) cited in: Prestwood, LE (2010). Architectural design factors of domestic violence shelters that affect outcomes for female domestic violence victims: a naturalistic inquiry to establish grounded theory for future research. A thesis Submitted to the Office of Graduate Studies of Texas A&M University in partial fulfilment of the requirements for the Degree of Doctor of Philosophy. Texas, US: Texas A&M University.

38. Hatjinikolaou, J. (2019). *The theory of embodiment and the coloured stain*. [Online] Available at: <https://www.blod.gr/lectures/h-theoria-tis-ensomatosis-kai-o-hromatikos-lekes/> [Accessed: 25th June 2020]

we feel about an environment or an individual. In addition, it can help us assess a place in terms of its harm or nourishment, yielding different degrees of comfort or anxiety.<sup>39</sup> An individual's quality of life within a home environment is determined by the dimensions of embodied realism that address both the physical and psychological aspects of the environment.<sup>40</sup>

As Day (2004)<sup>41</sup> states, 'Architecture, in the sense of environmental design, is the art of nourishing the senses'. Hence, it could be argued that the design of a shelter for vulnerable individuals could be developed in light of an understanding of the relationship between the design elements and the embodied sensory experiences.

## Objective 2

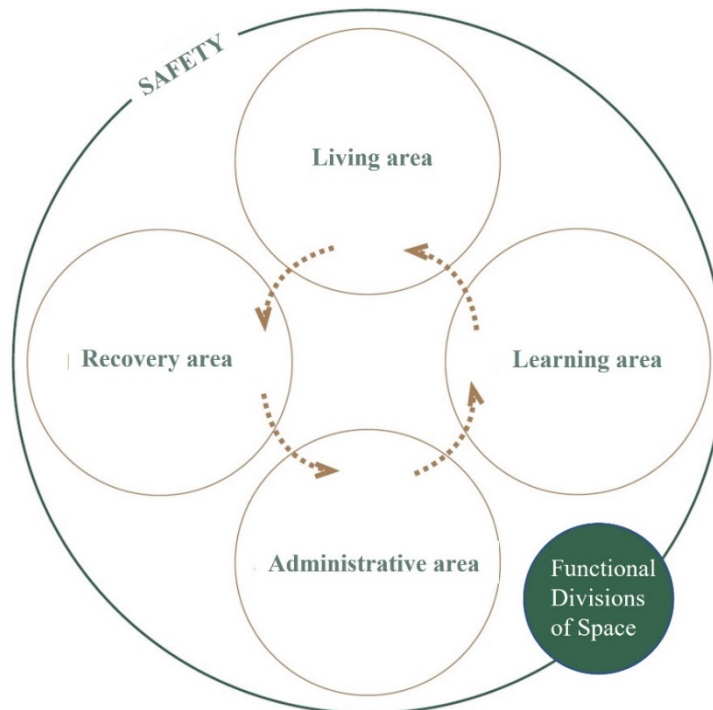
A building environment for female sex trafficking victims must offer a range of services that meet the needs of their residents and contribute to their healing process. Aside from the facilities required for their physiological needs, space is needed for the services that will empower them psychologically, develop their skills, and allow them to reintegrate into society over time. According to the collected data and the therapeutic design principles, the layout could be divided into distinct functional bubbles to accommodate privacy and social interaction, individual expression, reflection and discretion. Each of the four bubbles of function operates under the theme of 'safety' (Figure 3).

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39. Day, C. (2004). *Places of the Soul - Architecture and Environmental Design as a Healing Art* [Online] Oxford: Elsevier. Available from: [https://www.academia.edu/37164088/Places\\_of\\_the\\_Soul\\_Architecture\\_and\\_Environmental\\_Design\\_as\\_a\\_Healing\\_Art](https://www.academia.edu/37164088/Places_of_the_Soul_Architecture_and_Environmental_Design_as_a_Healing_Art) [Accessed: 30th June 2020]

40. Prestwood, LE (2010). *Architectural design factors of domestic violence shelters that affect outcomes for female domestic violence victims: a naturalistic inquiry to establish grounded theory for future research*. A thesis Submitted to the Office of Graduate Studies of Texas A&M University in partial fulfillment of the requirements for the Degree of Doctor of Philosophy. Texas, US: Texas A&M University. Available from: <https://core.ac.uk/download/pdf/147140403.pdf> [Accessed: 3rd July 2020]

41. Day, C. (2004). *Places of the Soul - Architecture and Environmental Design as a Healing Art* [Online] Oxford: Elsevier. Available from: [https://www.academia.edu/37164088/Places\\_of\\_the\\_Soul\\_Architecture\\_and\\_Environmental\\_Design\\_as\\_a\\_Healing\\_Art](https://www.academia.edu/37164088/Places_of_the_Soul_Architecture_and_Environmental_Design_as_a_Healing_Art) [Accessed: 30th June 2020]



**Figure 3.** *Functional Divisions of Space*

Source: Papadopoulou 2021.

Data: BC Housing (2017) and Lawson (2010)

The identification of key design features that have a significant impact on the healing outcomes of patients has been made based on the aforementioned studies and the collection of primary and secondary data from numerous sources.<sup>42 43 44 45 46 47</sup> These design features should be considered in the design of

42. Lawson, B. (2010) 'Healing architecture'. *Arts & Health*, [Online]Vol.2(2). pp. 95-108. Available from: [https://www.researchgate.net/publication/257353533\\_Healing\\_architecture?enrichId=rgreq-4aefb4e62600cb5178b108698e35f471-XXX&enrichSource=Y292ZXJQYWdlOzI1Nz M1MzUzMztBUzoyODQ0MTQxNzQwODkyMTdAMTQ0NDgyMTAzMTIxMg%3D%3D&el=1\\_x\\_3&\\_esc=publicationCoverPdf](https://www.researchgate.net/publication/257353533_Healing_architecture?enrichId=rgreq-4aefb4e62600cb5178b108698e35f471-XXX&enrichSource=Y292ZXJQYWdlOzI1Nz M1MzUzMztBUzoyODQ0MTQxNzQwODkyMTdAMTQ0NDgyMTAzMTIxMg%3D%3D&el=1_x_3&_esc=publicationCoverPdf) [Accessed: 21st June 2020]

43. Pearson, M. and Wilson, H. (2012) 'Soothing spaces and healing places: Is there an ideal counselling room design?'. *Psychotherapy in Australia*, [Online]Vol.18(3). pp 46-53. Available from: [https://www.researchgate.net/publication/254724357\\_Soothing\\_spaces\\_and\\_healing\\_spaces\\_Is\\_there\\_an\\_ideal\\_counselling\\_room](https://www.researchgate.net/publication/254724357_Soothing_spaces_and_healing_spaces_Is_there_an_ideal_counselling_room) [Accessed: 18th October 2019]

44. Ulrich, RS (2001) 'Effects of Healthcare Environmental Design on Medical Outcomes'. In *Design and Health: Proceedings of the Second International Conference on Health and Design* [Online] 49.pp. 59. Available from: [https://www.researchgate.net/publication/273354344\\_Effects\\_of\\_Healthcare\\_Environmental\\_Design\\_on\\_Medical\\_Outcomes](https://www.researchgate.net/publication/273354344_Effects_of_Healthcare_Environmental_Design_on_Medical_Outcomes) [Accessed: 7th December 2020]

45. Huisman, E.R.C.M., Morales, E., Van Hoof, J. and Kort, H.S.M. (2012) 'Healing environment: A review of the impact of physical environmental factors on users'. *Building and Environment* [Online] 58. pp.70-80. Available from: <https://doi.org/10.1016/j.buildenv.2012.06.016> [Accessed: 23rd November 2020]

46. Dellinger, B. (2010) *Healing Environments*. In: McCullough, C. (ed.). *Evidence-based Design for healthcare facilities*. [Online] Indianapolis: Renee Wilmeth. Available from: <http://docshare02.docshare.tips/files/7358/73586537.pdf> [Accessed: 7th December 2020]

47. Papadopoulou, F. (2020) *Architectural elements that play an important role in the designing of healing spaces*. [Interview] 1st December 2020.

either a hospital environment or a therapy room.<sup>41 42</sup> Incorporating these design principles will help to create a comfortable and inviting atmosphere, avoiding the feeling of an institutional environment.

## Design Principles

This section describes how the design criteria have been summarised into a list of design principles for designers of building environments for female sex trafficking victims. Each design principle is elaborated in turn as follows:

- Privacy

A space must be designed to give its occupants the option to choose between privacy and companionship following their preferences and needs in the course of their long recovery journey.

- Outdoor views and natural daylight

The design of the building must give the option of the outside view. Windows and openings that allow outdoor views and natural light help in stress reduction and dealing effectively with depression. Research has shown that patients who have access to view and natural daylight have a quicker recovery.

- Nature, biophilic scenes and other positive distractions

Having access to a natural environment and fresh air has therapeutic effects on an individual. Gardening has the potential to give people a sense of purpose since it is an act of nurturing and contributing to something. The benefits of nature cannot only be obtained by simply utilizing plants or having access to a garden, but also by implementing colours that are inspired by nature and that contrast and complement natural elements and textures, such as wood and stone.

- Control

Providing a space with optimal levels of heat, light, and sound (artificial or natural) and the ability to control them, has a profound impact on the environmental comfort of individuals. It is important to note that victims of sex trafficking lacked control for a considerable period of time. Being able to control their environment and experience a degree of independence can greatly facilitate their recovery process. Noise reduction and acoustics privacy are also important considerations. The ability to control seating arrangements during a counselling session can significantly enhance residents' feelings of comfort.

- Materials

Design elements, colours, materials, and textures that create a warm and inviting atmosphere are effective in creating a more relaxing environment. Positive emotions are evoked by the feeling of home/refuge, tidiness, and cleanliness. The evidence-based design suggests that inspiring spaces with elements of nature and intriguing colours have a profound impact on patient recovery. Using colour can help people divert their attention from internal mental tensions and focus on

external positive distractions. A healing environment can therefore utilize vibrant accent colours in combination with softer and calmer ones. The goal is to achieve a balance between a not too aggressive and not too monotone final appearance, according to the use of the room. For counselling rooms, colours that create an ambience of relaxation are preferred, along with softer materials such as carpeting. Room size may also affect an individual's psychological condition: too large or too small spaces can create feelings of insecurity or claustrophobia.

- Navigation

The design of the space needs to convey a clear sense of direction and establish clear distinctions among the various functions of the various areas. The elimination of confusion can help decrease stress and establish a sense of safety and privacy. This is particularly important in large therapeutic environments. Corridors and staircases must be wide enough to facilitate efficient and safe circulation for residents and staff.

- Facilities and staff

Providing amenities that enhance the sense of home, such as televisions, books, magazines, computers, etc. Spaces or rooms that are specifically designed for staff will enable them to work more efficiently.

Besides these prerequisites, spaces also need to meet specific functional requirements to meet the needs of their residents and facilitate their healing process. The rooms and spaces are generally determined by their size and the number of residents and staff members. Further, each space must be sized to ensure functionality, accessibility, efficient circulation, and to meet the physiological and psychological needs of the residents.

Design principles require that all rooms have access to natural light and air. It is however imperative that each area and room within a building's structure is organized in a manner that safeguards the residents' safety. Several factors should be considered, including the type and location of windows; windows could be placed on exterior walls, provided that they are not directly accessible from the street, or they could be placed on internal walls facing an internal garden or courtyard. To ensure the safety and security of the building, exterior areas, corridors, staircases, and elevators must be adequately illuminated and there must be non-slip materials used in areas such as kitchens, bathrooms, and the entranceway. In addition, security cameras and security mechanisms must be installed. In addition, to maintain the highest level of discretion and avoid the appearance of an institutional exterior, it is also important to use materials and colours that harmonize with the surrounding environment<sup>48</sup>. To enhance the sense of safety and comfort for both participants, the design of the counselling rooms could incorporate two doors/entrances at either end; in case of discomfort during

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48. BC Housing (2017). *Shelter Design Guidelines*, [Online] Available at: <https://www.bchousing.org/publications/Shelter-Design-Guidelines.pdf> [Accessed:15 October 2020]

the session, one may leave without having to pass the other individual<sup>49</sup>. Lockable storage solutions should be available in the medical care area, the nurse's office, the resident's bedrooms and all the rooms in the administrative area. Soundproofing is required in every area. There should be a minimum width of 1.2m in all corridors and staircases.<sup>50</sup>

In each bubble of function, there are several rooms and spaces:

### Living Area

- Private bedrooms: There should be one en-suite bedroom for each resident with a lockable door that is equipped with the basic amenities (bed, side table, wardrobe) in addition to additional amenities, if space allows (such as a desk, armchair, shelves), including independent lighting and temperature control. Min. size: 9m<sup>2</sup>
- Laundry room: The facility should have two laundry rooms, each fitted with necessary appliances (washing machines, dryers, sinks, ironing boards and irons) for both staff and residents; one for staff use (bed sheets, towels, cleaning and maintenance equipment) and the other for residents' personal use. According to the number of women being housed, the number of facilities will vary.
- Kitchen: For women to prepare meals, a kitchen counter space (min. size: 4m in total) needs to be equipped with the necessary equipment and electric appliances (sink, dishwasher, microwave, stove, refrigerator, coffee machine) as well as sufficient cupboards and shelves for storage. The installation of a kitchen island with bar stools will facilitate the delivery of cooking lessons that will enable women to learn new skills.
- Dining room: Seating arrangements to accommodate the maximum number of women. Tables for 2-4 users combined with a bar countertop and bar stools would enable such a setup to be achieved.
- Living room / Communal area: Seating arrangements for an average number of women consisting of a mixture of sofas, armchairs, and chaise longues, enabling socializing or relaxation.
- TV / Cinema room: Seating arrangements for an average number of women consisting of sofas and armchairs, TV and satellite installation and a projector for movies.
- Fitness area: An indoor area equipped with fitness and exercise equipment (aerobic, gym, etc.) capable of accommodating an average number of women. An outdoor area equipped for outdoor exercises and/or games.
- Restroom (WC): A communal restroom located in the Living Area. Min. size: 6m<sup>2</sup>

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49. Papadopoulou, F. (2020) *Architectural elements that play an important role in the designing of healing spaces*. [Interview] 1st December 2020.

50. GOV.UK (2015). *The building regulations 2010 – Access to and use of buildings – Volume 2 Buildings other than dwellings*. [Online]. Available at: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/441786/BR\\_PDF\\_AD\\_M2\\_2015.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/441786/BR_PDF_AD_M2_2015.pdf) [Accessed: 31st October 2020]



- Garden / Courtyard: An indoor garden or an assortment of smaller gardens inside the complex (flower gardens, vegetable gardens, green space, etc.) together with the arrangement of seating for isolation, socialization, and group work activities. Area size should be proportional to the size of the complex.

### **Learning Area**

- Computer training room: A computer classroom suitable for teaching computer skills to the maximum number of women.
- Educational training room: A classroom to accommodate the maximum number of women where different classes or seminars can be conducted, depending on the needs of the women. Through these sessions, they will be able to gain skills that will assist them in their future employment search and adjustment to society, such as language skills and everyday life skills.
- Meeting room for assistance and advice: An office desk in a room where women who require private meetings can talk with support staff members about private matters (e.g., legal assistance, job placement assistance). Min. size: 6m<sup>2</sup>
- Library-Reading room: A study space equipped with books, magazines, and computers available, designed with seating arrangements to accommodate an average number of women for study and relaxing reading (tables, chairs, armchairs).
- Restroom (WC): A communal restroom located in the Learning Area. Min. size: 6m<sup>2</sup>

### **Recovering Area**

- Medical care / Examination room: An examination room equipped with all the necessary equipment (examination bed, lockable cabinet for medical supplies, sink, countertop, and office desk) to facilitate medical procedures conducted by outside medical professionals. Min. size: 14m<sup>2</sup>
- Nurse's office: An appropriately furnished workspace, including a desk, chairs, storage solutions for residents' medical records, and all necessary communication and computer equipment. Min. size: 6m<sup>2</sup>
- Counselling room: A room adequately equipped for private counselling sessions, including desks, chairs, storage solutions, and armchairs. Min. size: 12m<sup>2</sup>
- Room for group meetings, group therapy: A room equipped for group meetings and group therapy sessions for the maximum number of women.
- Arts & Crafts room: An area for the storage of art and craft equipment and furniture (tables, shelving units, sinks) for the average number of women.
- Art & Music Therapy room: An arts and music therapy room with sufficient furniture and equipment to accommodate an average number of women.

- Restroom (WC): A communal restroom located in the Recovering Area. Min. size: 6m<sup>2</sup>

### **Administrative Area**

- Staff's bedrooms: Bedrooms with ensuite facilities and lockable doors for staff members who are required to remain indoors during the night (such as social workers, carers, nurses, etc.). Min. size: 9m<sup>2</sup>
- Staff's Restroom (WC): Restrooms (men and women) near the staff's offices for staff use only. Min. size: 6m<sup>2</sup>
- Staff's kitchen: A kitchen countertop (min. size: 2m) with essential kitchen equipment and electric appliances (sink, dishwasher, oven, microwave, hob, fridge, coffee maker) as well as adequate cupboard space for meal preparation by staff members. A dining table with 4-6 chairs should also be available.
- Manager's office: An office workspace equipped with a desk, chairs, storage facilities, and all the necessary communication and computer equipment. Min. size: 8m<sup>2</sup>
- Staff's office: An open plan office with sufficient space and furnishings appropriate for the number of staff members using it, equipped with all the necessary communication and computer equipment.
- Meeting room: A room adequately equipped to accommodate a meeting for 10 people, including all communication and computer equipment.
- Security office: A room located adjacent to the reception and entrance area adequately furnished and equipped with the necessary facilities and equipment (e.g. CCTV). An adequate view of the street and the building's entrance is essential for the security staff.
- Reception area: An area adjacent to the main entrance for the new residents to be greeted upon arrival, which includes a reception desk, storage areas and seating arrangements.
- Storage room: An area with storage solutions (cabinets, shelves, refrigerator, freezer) for storing fresh and dry foods. This area must be adjacent to the loading area.
- Loading area: To facilitate easy delivery of the house's supplies, a loading area should be provided adjacent to the storage rooms.

### **Parametric Analysis**

Once the relevant design principles have been identified, we explored ways in which these principles can be combined into optimal and intelligent solutions. We implemented two different methods to generate an array of possible spatial arrangements and compared the results. The design principles were translated into an adjacency map, which was utilised as an input for the two methods.

## Adjacency Network

Following the analysis of the above data, a network of adjacencies has been developed to achieve optimal functionality of the space (Appendix 1: Adjacency network). An adjacency map is a helpful tool to systematise different activities in a complex programme, identifying significant nodes and mutual dependencies among the activities (Figure 4).

A detailed spreadsheet is also given, which outlines the functional requirements (needs) of each room and identifies the hierarchy of these requirements based on the Design Principles and the activities that occur in each room (Appendix 2: Hierarchy of functional requirements). Through the exploration of current computational tools for automatic space configuration, two computational design methods have been examined as part of the study of this project: the Squarified Treemap and the Magnetising Floor plan Generator.



**Figure 4.** *The Network of Adjacencies of Spaces. Activities are Here Represented as Nodes in a Graph Structure. Different Colours Indicate Different Clusters of Activities, Following the Adjacency Study*

Source: Papadopoulou 2021.

## The Squarified Treemap

The Squarified Treemap algorithm<sup>51</sup> was developed to provide graphical representations of hierarchical information in an optimised manner for regular

51. Bruls, M., Huizing, K. & Wijk, J.J.V. (2000). 'Squarified treemaps'. *Data visualization 2000*. [Online] pp. 33-42. Springer, Vienna. Available from: <http://diglib.org/bitstream/handle/>

layouts. The Squarified Treemap is a variant of the more common Treemap algorithm<sup>52</sup> that represent a full hierarchical data structure into adjacent squares based on their relationship in the data tree. Depending on their relationship, data can be represented with elongated rectangles. The Squarified Treemap algorithm improves this, approximating areas to squares. Marson and Musse (2010)<sup>53</sup> implemented this algorithm for the production of floor plans in gaming environments. With its application in spatial configuration, it is possible to produce accurate interior layouts with information about their characteristics. For this study, we used an implementation developed by Thomas Holth (2017)<sup>54</sup> on the code developed by Uri Laserson (2022).<sup>55</sup> The design process begins with the identification of the layout parameters that have derived from the Design Principles of a building environment for female sex trafficking victims.

#### List of actions

1. Identification of the Design Principles that can be translated into 'space':
  - Navigation: maximisation of the efficiency of circulation by securing:
    - a. clear areas of function
    - b. min. width of corridors
  - Outdoor views: specific rooms' connection to the garden (Appendix 1: Adjacency network)
    - a. Dining room
    - b. Living room
    - c. Fitness area
    - d. Counselling room
    - e. Arts & Crafts room
    - f. Arts & Music Therapy room
2. Rooms with a fixed position (according to Adjacency network):
  - a. Garden: to be placed centrally in the layout
  - b. Security office: to be placed next to the entrance area
  - c. Reception area: to be placed next to the entrance area
  - d. Loading area: to be placed next to the exterior wall
3. Rooms connected to each other, apart from (1. a-f) (Appendix 1: Adjacency network):
  - a. Kitchen - Dining room

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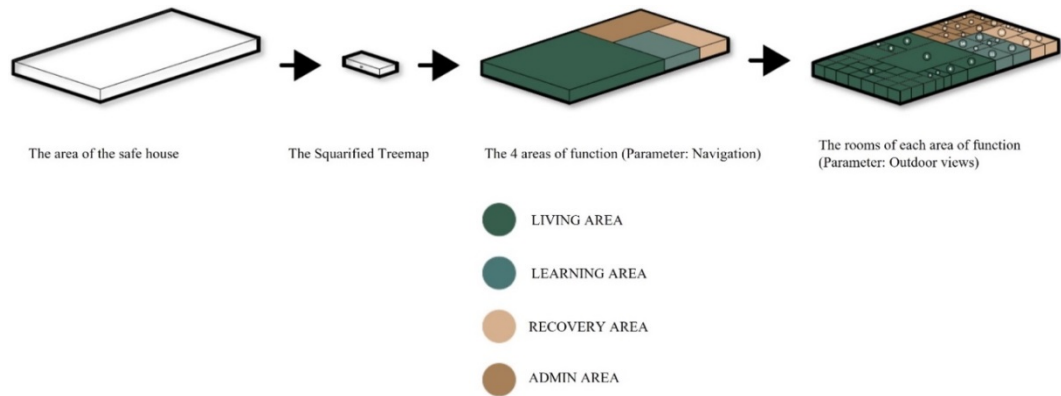
52. Shneiderman, B. (1992). 'Tree visualization with tree-maps: 2-d space-filling approach'. *ACM Transactions on graphics (TOG)*, [Online] 11(1), pp.92-99. Available from: <https://doi.org/10.1145/102377.115768> [Accessed: 6th April 2022]

53. Marson, F. & Musse, S. (2010). 'Automatic Real-Time Generation of Floor Plans Based on Squarified Treemaps Algorithm'. *International Journal of Computer Games Technology*, [Online] 2010, Article ID 624817. Available from: <https://doi.org/10.1155/2010/624817> [Accessed: 26th March 2021]

54. Holth, T. (2017). *Treemap*. Available from: Grasshopper3d.com <https://www.grasshopper3d.com/forum/topics/treemap> [Accessed: 6th April 2022]

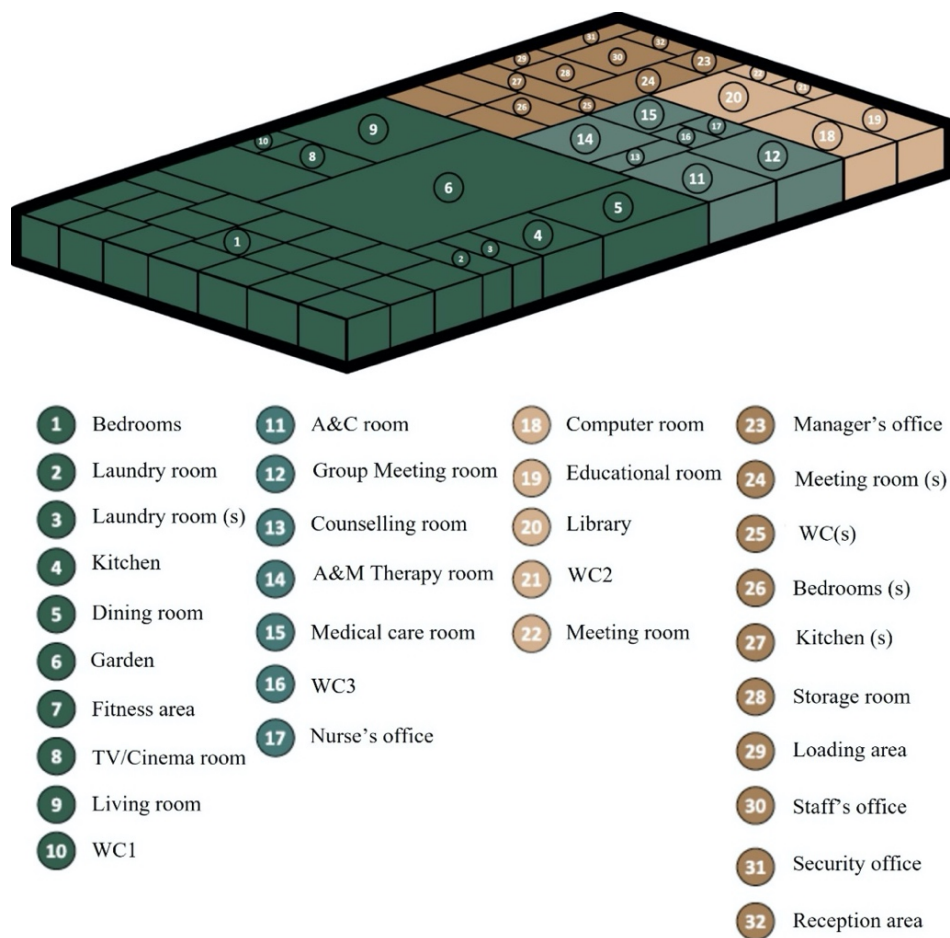
55. Laserson, U. (2022). *Squarify*. [Online] 2nd September 2021. Available from: <https://github.com/laserson/squarify> [Accessed: 6th April 2022]

- b. Medical care room - Nurse's office
  - c. Storage room - Loading area
- 4. Rooms close to each other (Appendix 1: Adjacency network):
  - a. Bedrooms – Laundry room - Laundry room (staff)
  - b. Bedrooms – Kitchen
  - c. Living room – WC 1
  - d. Living room - TV/Cinema room
  - e. Computer Training room – Library – Educational Training room – WC 2
  - f. Meeting room - WC 2
  - g. Medical care room – WC 3
  - h. Nurse's office – Counselling room
  - i. Group meeting room – Arts & Crafts room – Art & Music Therapy room – WC 3
  - j. Staff's bedrooms – Staff's kitchen
  - k. Staff's kitchen – Staff's office
  - l. Staff's kitchen – Storage room
  - m. Manager's office – Staff's office – Staff's Meeting room – Staff's WC
  - n. Security office - Reception area
  - o. Reception area - Staff's office
- 5. Definition of the parameters of the algorithm:
  - a. Navigation  
 Index: Efficiency of circulation  
 Objective: maximize /optimize the width of corridors
  - b. Outdoor views  
 Index: Position of rooms in relation to garden  
 Objective: allocate the optimal position of each room
- 6. Based on the areas of the rooms, a curve (rectangle) in Rhino was set as a boundary for defining the spatial configuration of the building environment and was connected to the Squarified Treemap component.
- 7. The Treemap algorithm divided the rectangle (the area of the building environment) into the four areas of function which contribute to the clear navigation throughout the building (Parameter: Navigation) (Figure 5).
- 8. Each area was further subdivided into the various rooms it contains. In the bedroom areas (resident bedroom area: 20 bedrooms, staff bedroom area: 4 bedrooms) the rooms were randomly placed (some rooms were placed in the middle of the area) (Figure 6). The numerical order by which the areas of the rooms were imported into the Treemap algorithm had to be taken into consideration and rearranged manually according to the Design Principles and the requirements of previous steps (steps 2, 3 and 4).



**Figure 5.** *The Squarified Treemap Process*

Source: Papadopoulou 2021.



**Figure 6.** *The Rooms within the Areas of Function*

Source: Papadopoulou, 2021.

### The Drawback of Squarified Treemap

- The different areas of function and rooms were organised following an optimised strategy based on an ordered list of areas (from larger to smaller). As the driving criterion here was to fill in all available space into squared areas, this method resulted in the programmatic functions arranged only by size, with no consideration of the adjacency. The result did not adhere to the parameters set (Design Principles and fixed position of specific rooms). To ensure the implementation of the parameters, the order in which the areas of the rooms were imported into the algorithm had to be taken into consideration and manually rearranged.
- The Squarified algorithm develops the spatial configuration within a specific boundary (a curve) in Rhino; a given predefined space is required for the algorithm to work. As a consequence, there are fewer options available for designing a layout that optimally adheres to the Design Principles.

### Use of a Genetic Algorithm (GA) with the Squarified Treemap Algorithm

In order to improve the allocation of areas using this approach, including the parameters set and the links between rooms, a Genetic Algorithm (GA) was used to determine the optimal placement of specific rooms.

1. A GA was applied to determine the optimal location of bedrooms in the bedroom area in relation to the garden, (Parameter: Outdoor view). As a result of this process, various solutions were generated.
2. A GA was applied to minimise the distance between the specific rooms that must be connected to the garden (control adjacency) to ensure the optimal placement of each room (Parameter: Outdoor Views). There was no alteration to the initial layout solution created by the Squarified Treemap algorithm during this process.
3. A GA was applied to minimise the distance between the rooms that must be connected to each other (control adjacency) to ensure the optimal placement of each room (Parameter: Navigation). There was no alteration to the initial layout solution created by the Squarified Treemap algorithm during this process.
4. A GA was applied to minimise the distance between the rooms that must be close to each other (control adjacency) to ensure the optimal placement of each room (Parameter: Navigation). This process was not completed since the previous ones failed to produce any results.

### The drawback of the Genetic Algorithm with the Squarified Treemap

- Applying a GA in steps 2, 3 and 4 did not produce any usable solutions. The number of rooms was too small and the requirements for the arrangement of these rooms were already met optimally; the numerical order by which the size of the rooms was listed in the Treemap algorithm, following the Design Principles and the requirements described in the steps 2, 3 and 4, was rearranged manually, where necessary.

- Applying a GA in step 1 generated various solutions for the location of bedrooms with minimum distance to the garden (Parameter: Outdoor Views). However, some of the rooms that were generated had odd shapes as the algorithm optimises the shape of the rooms based on their sizes listed in the algorithm.

### The Magnetising Floor Plan Generator (MFG)

This algorithm<sup>56</sup> is designed to generate the spatial configuration of public buildings with specified adjacencies between their interior spaces. It allows the user to enter the basic features of each room and calculates the corridors around each room. Different options within various parameters can lead to different results, from which the best is selected according to the evaluation function<sup>57 58</sup>.

#### List of actions

1. A network of adjacencies was created between rooms following the Adjacency network (Figure 4) and the name and area value of each room was imported. Adding two more links (kitchen – storage room and living room – library) allowed all the areas of functions to be connected (Appendix 3: Adjacency network B) (Figure 7).
2. One room was set as an entrance (reception area). The location of the reception area and the security office must be adjacent to the entrance area (Figure 7).
3. A curve (rectangle) and a point are created in Rhino to establish the boundaries within which the layout will be developed, as well as the location of the building entrance and are both connected to the MFG algorithm.

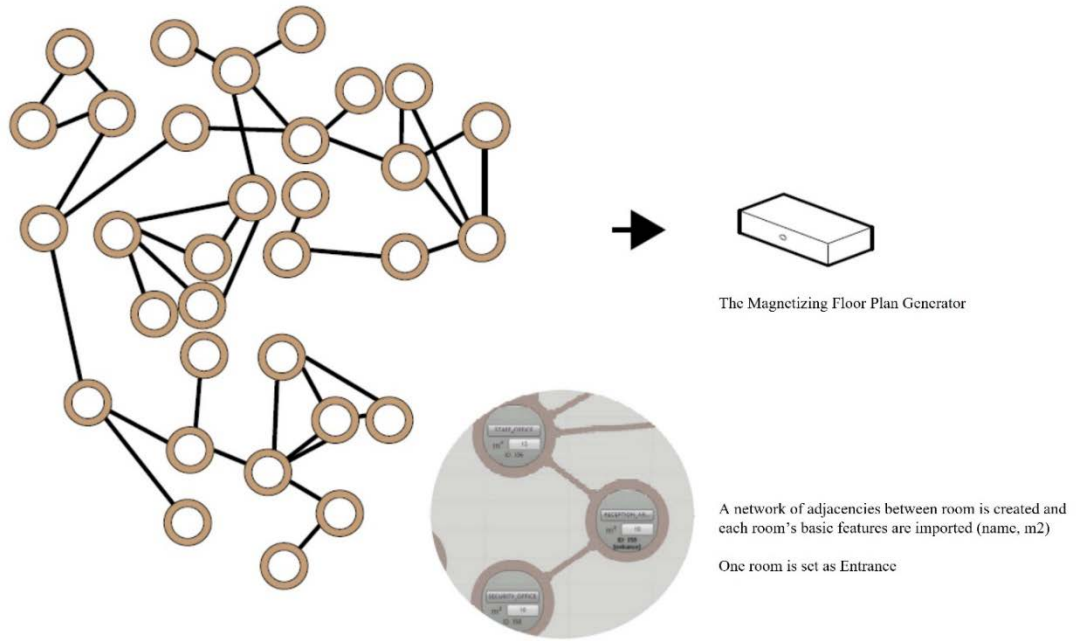
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56. Egor, G., Sven, S., Martin, D. & Reinhard, K., (2020). 'Computer-aided approach to public buildings floor plan generation. Magnetizing Floor Plan Generator'. *Procedia Manufacturing*, [Online] 44, pp.132-139. Available from: <https://doi.org/10.1016/j.promfg.2020.02.214>. [Accessed: 9th April 2022]

57. Bielik, M. (2019). *Magnetising Floor Plan Generator*. [Online] Available from: <https://toolbox.decodingspaces.net/magnetizing-floor-plan-generator/> [Accessed: 26th March 2021]

58. Hellguz (2021). *Magnetizing Floor Plan Generator* [Online] Available from: <https://www.food4rhino.com/en/app/magnetizing-floor-plan-generator> [Accessed: 26th March 2021]

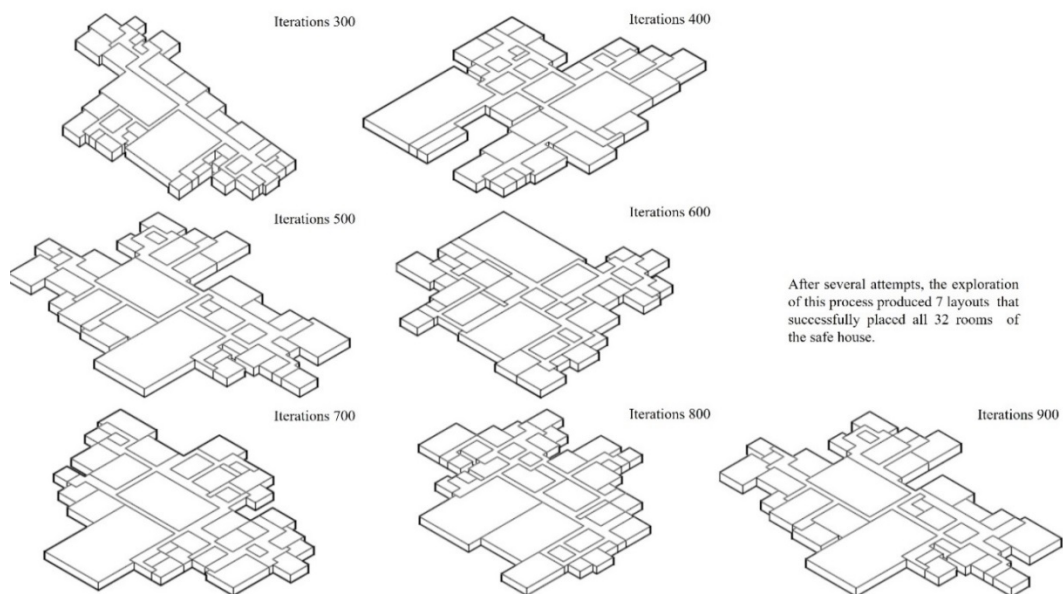




**Figure 7.** *The Magnetising Floor Plan Generator Process*  
 Source: Papadopoulou, 2021.

The algorithm ran the connections between rooms according to three parameters: the number of iterations, the maximum distance between rooms and the type of corridors. Different layouts were generated as previews according to these parameters.

After several attempts, the exploration of this process produced 7 layouts that successfully placed all 32 rooms of the building environment (Figure 8).



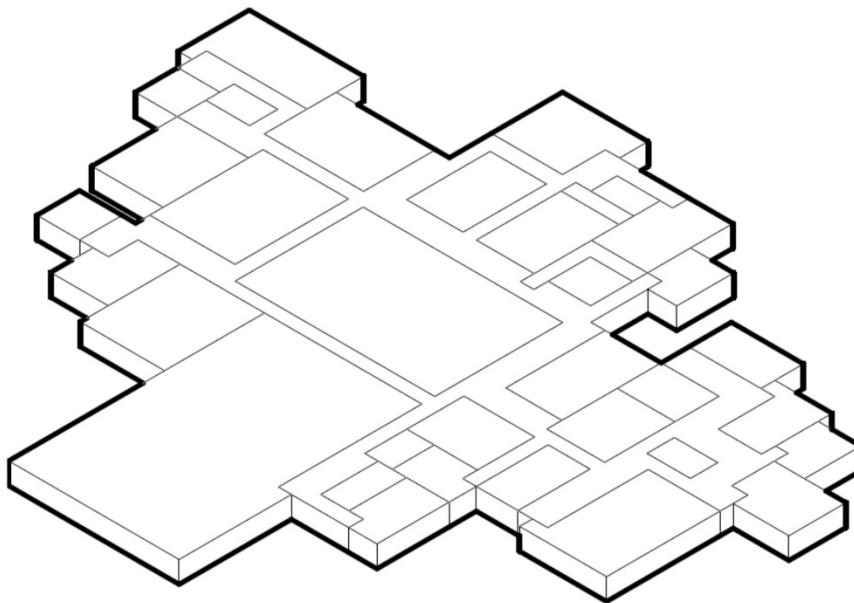
**Figure 8.** *The Layouts with Iteration 300, 400, 500, 600, 700, 800, 900*  
 Source: Papadopoulou, 2021.

### The Drawback of MFG

The connection between the rooms' network and the algorithm could not be saved and the preview layouts were lost. Once the file was reopened, new connections were required, and new preview layouts were produced. The preview layouts were converted to editable geometry, which resulted in layouts with no discernible borders between the different rooms. The layouts with the best spatial configuration, according to the Design Principles, were converted to PDF and imported into AutoCAD, where they were processed, adjusted and worked on in detail.

### The chosen layout

In comparison with the rest of the solutions produced, the layout with Iterations: 700 was chosen as the one that had the optimal spatial configuration based on the Design Principles (Figure 9).



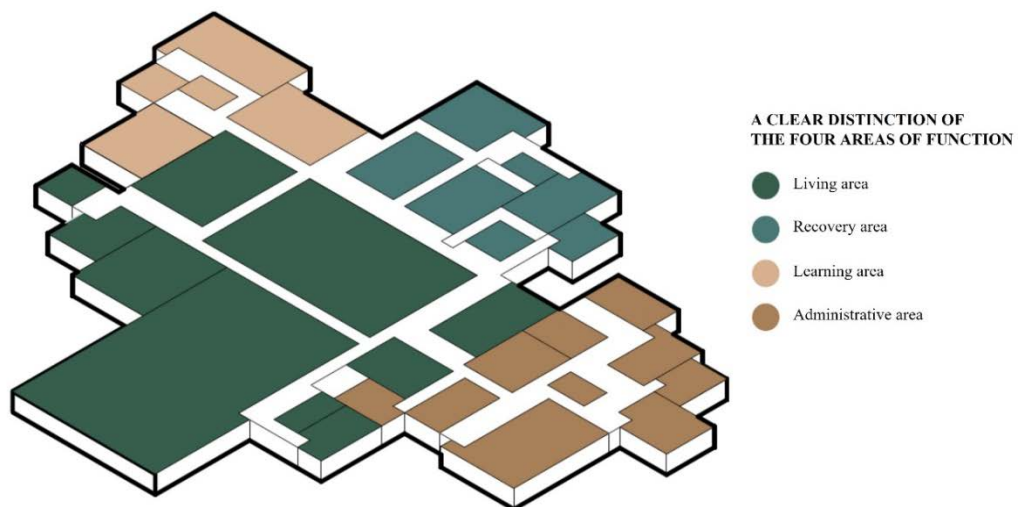
**Figure 9.** *The Optimal Layout (Iterations: 700)*

Source: Papadopoulou, 2021.

The following specifications were met:

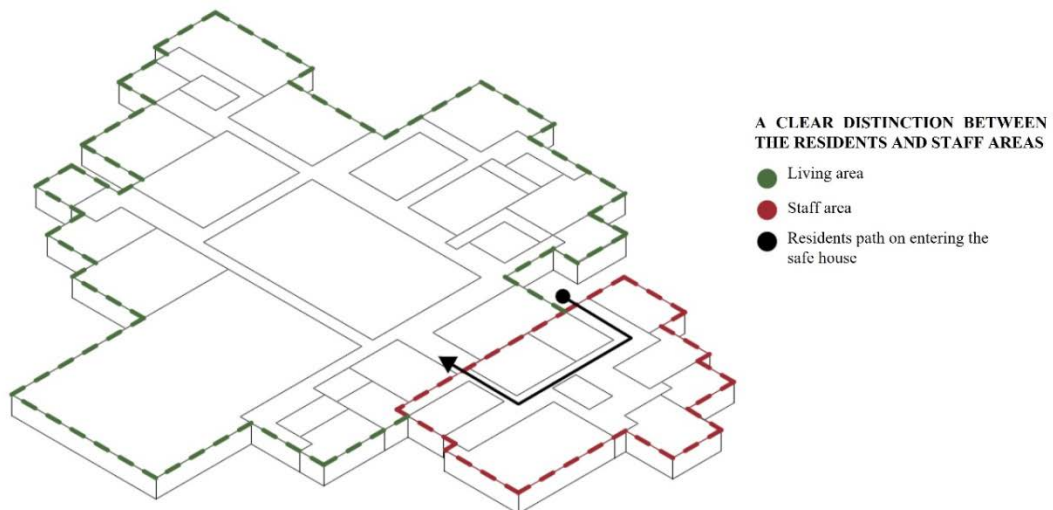
- The four areas of function (living area, recovery area, learning area, administrative area) are clearly defined ensuring the efficient circulation of the residents (Figure 10).
- Residents and staff areas are clearly defined, which, alongside the location of the entrance area, contributes to the feeling of safety, security, and isolation that the women experience both during their stay and upon entering the building environment after being rescued (Figure 11).
- The garden is positioned in the centre of the establishment for maximum security and privacy (Figure 12).

- The positioning of the garden ensures the connection between specific rooms and the garden and the maximum number of rooms with a view of the garden (Figure 13).
- The placement of the rooms with fixed positions, according to the Adjacency network, is secured: garden - centrally placed, security office and reception area - next to the entrance area (surveillance, accessibility), loading area - next to the exterior wall (for speeding up the refilling process) (Figure 14).
- The required adjacencies between specific rooms are ensured (Appendix 3: Adjacency network B and Appendix 4: Adjacency network B-Connections) (Figures 15-16).



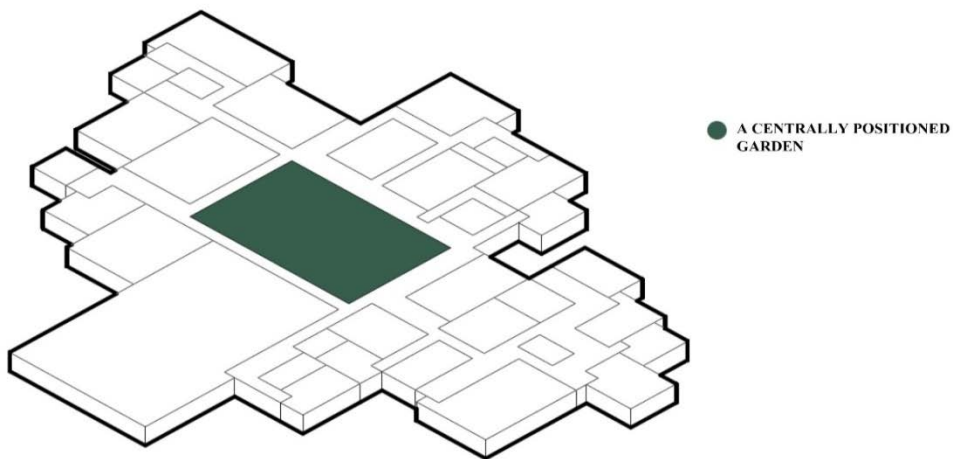
**Figure 10.** *A Clear Distinction between the Four Areas of Function*

Source: Papadopoulou, 2021.

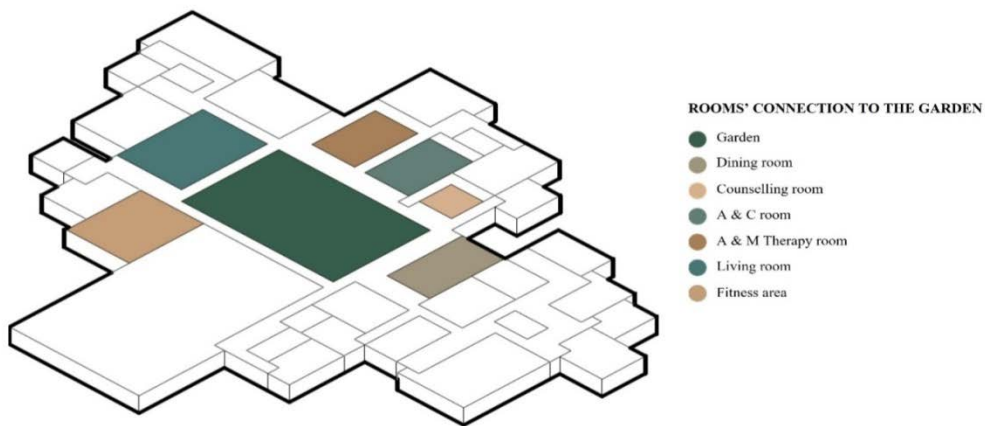


**Figure 11.** *A Clear Distinction between the Residents and Staff Areas*

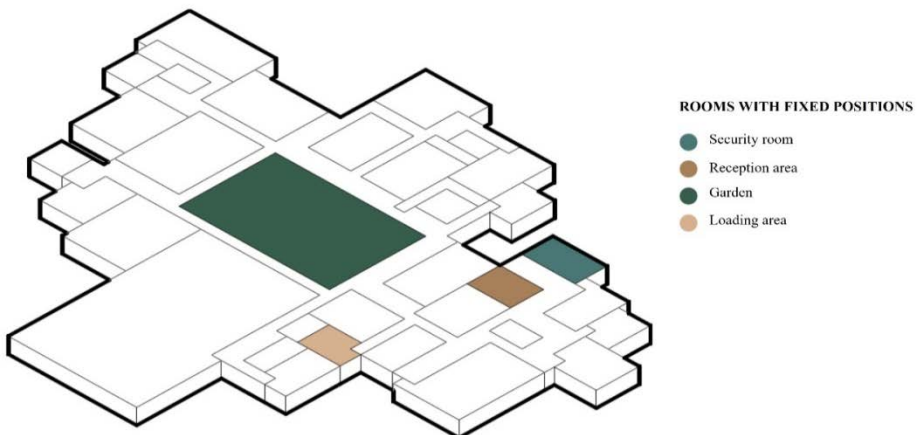
Source: Papadopoulou, 2021.



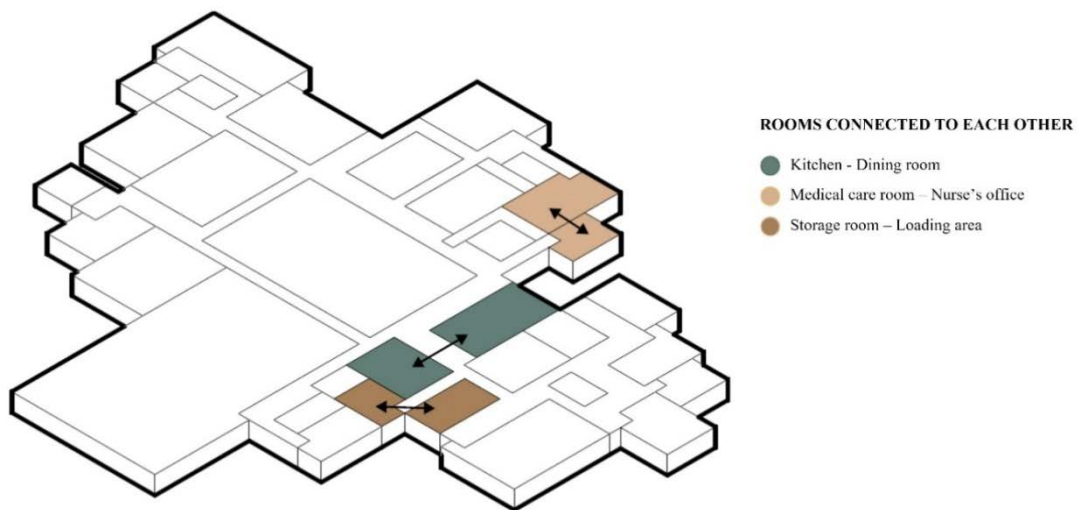
**Figure 12.** *A Centrally Positioned Garden*  
 Source: Papadopoulou, 2021.



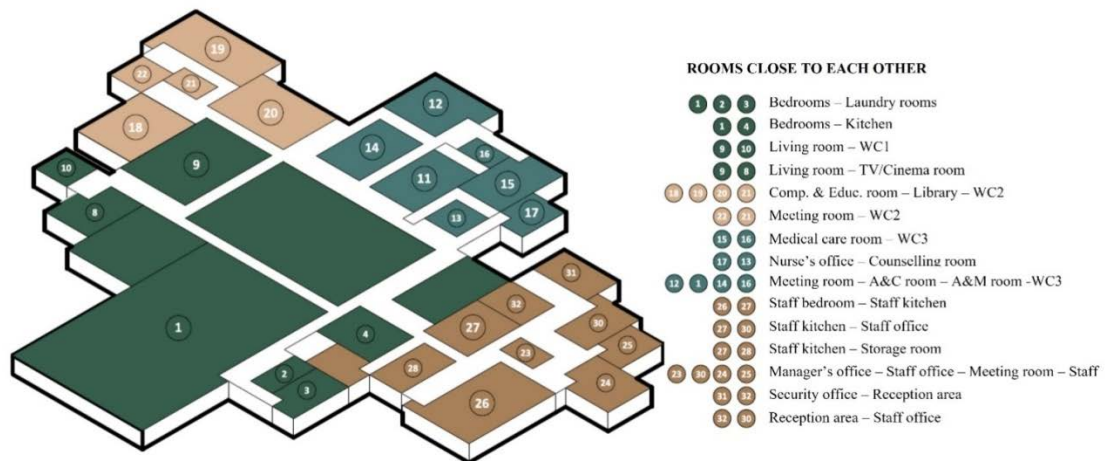
**Figure 13.** *Rooms' Connections to the Garden*  
 Source: Papadopoulou, 2021.



**Figure 14.** *Rooms with Fixed Positions*  
 Source: Papadopoulou, 2021.



**Figure 15.** *Rooms Connected to Each Other*  
 Source: Papadopoulou, 2021.



**Figure 16.** *Rooms Close to Each Other*  
 Source: Papadopoulou, 2021.

## Discussion

The aim of this study was to establish and define design principles and investigate the use of a parametric design method for the design of a building environment for female sex trafficking victims. The design of the built environment was based on a set of specific design principles that could serve as a determining factor in the recovery process for these women through a computational model that would allow for deeper exploration of the design.

Based on the collection and analysis of primary and secondary data, seven design principles were identified that must be adhered to in the design of such spaces. The parameters for the two algorithms that were tested were chosen from the Design Principles that can be translated into 'space'. During this process,

several problems and drawbacks were encountered, which ultimately led to the selection of the Magnetizing Floor Plan Generator algorithm as the most appropriate for this research. Using the findings of MFG, a space was produced that included the criteria established during the design process (the location of specific areas and connections between rooms), allowing for a controlled link between the interior and exterior environments. It generated layouts that, to the greatest extent possible, met the parameters set without being constrained by a predefined shape or boundary. A range of solutions of varying shapes was developed, allowing the designer to investigate and select the one with the optimum spatial layout.

In contrast, The Squarified Treemap required a predetermined fixed shape or boundary to generate spatial layouts, resulting in fewer design alternatives that optimally adhered to the Design Principles. In addition, various manual actions were required to ensure that the parameters were applied.

Through the use of a computational model, a significant number of alternative options were rapidly developed that met the criteria set. From these, the designer selected the one that best represented the optimal spatial configuration. The design principles that could be translated into space (outdoor views and navigation) were selected on the basis of rooms' arrangement and their adjacencies. From there, the designer's expertise may ensure the overall formation of the Design Principles, combining all aspects of them into the design, in order to create a therapeutic environment that supports and empowers women in the rehabilitation process.

### **Future Work**

Further development in the field of building environments for female sex trafficking victims using a parametric design approach can focus on several key areas. Firstly, a physical visit to relevant spaces and the collaboration with individuals directly involved in the operation and utilization of these spaces would provide real-life perspectives, helping us better understand and address space organization and safety concerns. Additionally, expanding the research to include a broader global examination of shelter experiences for such women, considering specific challenges faced in different countries and diverse social and economic conditions (for example populations in very difficult situations like those affected by the Ukrainian war), would enhance our understanding of their unique needs.

Furthermore, in future studies, it is important to consider and test a wider range of computational methods to fully explore the capabilities of the parametric design approach for the project at hand. While the current study has demonstrated the potential of parametric design in developing building environments for female sex trafficking victims, there is still room for further exploration and experimentation, including the feedback from residents and staff of the facilities.

Lastly, future work could consider adopting a three-dimensional (3D) design approach by incorporating multi-level structures, the entire building envelope, and immediate surroundings. This comprehensive perspective would optimize space utilization, improve functionality, and provide benefits such as enhanced outside views and security.

By exploring these areas, future studies can contribute practical design solutions that effectively support and empower female sex trafficking victims, enhancing our knowledge and ensuring the creation of safer and more accommodating building environments for these vulnerable individuals.

## Conclusions

The design of building environments for sex trafficking victims has not been sufficiently studied and there are no specific design instructions in contrast to various studies for guidelines for abuse victims' accommodation. However, it is equally crucial to ensure that the design of the accommodation in which sex trafficking victims are placed will work towards their healing process and emotional support, together with the meeting of their needs. This research was conducted with the belief that the building environments for sex trafficking victims are more than secure settings for sleeping and addressing practical needs; they are rather environments that offer protection, shelter and care without being perceived as asylums. Ideally, they should be viewed as places that help the abused individuals develop a sense of belonging, connection and intimacy, as well as prepare the ground for them to take the steps necessary to regain their self-respect and eventually reintegrate back into society.

In this research, a parametric design method was used to develop a building environment for female sex trafficking victims. Using a computational model that could lead to deeper design exploration, this research aimed to design the built environment based on specific design principles that could play a critical role in the recovery process of these women. By analysing their unique design and considering all the relevant parameters and stakeholders, this study investigated how the building environment could help these women recover and set the groundwork for their independent return to society.

This research was focused on female sex trafficking victims. However, the results of this project may also apply to victims of other types of trafficking or abusive environments.

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Appendix 1. Adjacency Network

Επίπεδο	BEDROOM	LAUNDRY ROOM	LAUNDRY ROOM (STAFF)	KITCHEN	DINING ROOM	LIVING ROOM	TV/CINEMA ROOM	FITNESS AREA	WC 1	GARDEN	COMPUTER TRAINING ROOM	EDUCATIONAL TRAINING ROOM	MEETING ROOM	LIBRARY	WC 2
BEDROOMS		X	X	X											
LAUNDRY ROOM	X		X												
LAUNDRY ROOM (STAFF)	X	X													
KITCHEN	X				X										
DINING ROOM				X	X										
LIVING ROOM							X		X						
TV/CINEMA ROOM						X									
FITNESS AREA										X					
WC 1						X									
GARDEN					X	X		X							
COMPUTER TRAINING ROOM												X		X	X
EDUCATIONAL TRAINING ROOM											X			X	X
MEETING ROOM															X
LIBRARY											X	X			X
WC 2											X	X	X	X	
MEDICAL CARE ROOM															
NURSE'S OFFICE															
COUNSELLING ROOM										X					
GROUP MEETINGS ROOM															
ARTS & CRAFTS ROOM											X				
ART & MUSIC THERAPY ROOM											X				
WC 3															
STAFF'S BEDROOMS															
STAFF'S WC															
STAFF'S KITCHEN															
MANAGER'S OFFICE															
STAFF OFFICE															
STAFF MEETING ROOM															
SECURITY OFFICE															
RECEPTION AREA															
STORAGE ROOM															
LOADING AREA															

X & colour = which rooms must be connected to each other  
 X = which rooms must be close to each other

Επίπεδο	MEDICAL CARE ROOM	NURSE'S OFFICE	COUNSELLING ROOM	GROUP MEETING ROOM	ARTS & CRAFTS ROOM	ART & MUSIC THERAPY ROOM	WC 3	STAFF'S BEDROOM	STAFF'S WC	STAFF'S KITCHEN	MANAGER'S OFFICE	STAFF OFFICE	STAFF MEETING ROOM	SECURITY OFFICE	RECEPTION AREA	STORAGE ROOM	LOADING AREA
BEDROOMS																	
LAUNDRY ROOM																	
LAUNDRY ROOM (STAFF)																	
KITCHEN																	
DINING ROOM																	
LIVING ROOM																	
TV/CINEMA ROOM																	
FITNESS AREA																	
WC 1																	
GARDEN			X		X	P											
COMPUTER TRAINING ROOM																	
EDUCATIONAL TRAINING ROOM																	
MEETING ROOM																	
LIBRARY																	
WC 2																	
MEDICAL CARE ROOM		X					X										
NURSE'S OFFICE	X		X														
COUNSELLING ROOM		X															
GROUP MEETINGS ROOM					X	X	X										
ARTS & CRAFTS ROOM					X	X	X										
ART & MUSIC THERAPY ROOM					X	X	X										
WC 3	X				X	X	X										
STAFF'S BEDROOMS										X							
STAFF'S WC											X	X	X				
STAFF'S KITCHEN								X			X	X	X			X	
MANAGER'S OFFICE									X		X	X	X				
STAFF OFFICE									X	X	X	X	X		X		
STAFF MEETING ROOM									X	X	X	X	X		X		
SECURITY OFFICE														X			
RECEPTION AREA												X					
STORAGE ROOM										X							X
LOADING AREA																X	X

X & colour = which rooms must be connected to each other  
 X = which rooms must be close to each other







## HIERARCHY OF FUNCTIONAL REQUIREMENTS

ADMINISTRATIVE AREA	Staff's bedrooms		Degree	Staff's Restroom (WC)		Degree
	sleep	bed, side table	10	personal hygiene	toilet, sink, mirror	10
security	lockable doors	9	privacy	lockable doors	9	
personal hygiene	bathroom with toilet, sink, shower, mirror	8	fresh air / natural ventilation	window (not accessible from the street)	8	
light control	choise of functional, mood, general lighting	7				
temperature control		6				
storage	wardrobe, chest of drawers	5				
natural light / fresh air	window (not accessible from the street)	4				
min. size 9m2		Total: 9m2	next to staff's offices / min. size 6m2		Total: 6m2	

Corridors and staircases should have a min. width of 1.2m

ADMINISTRATIVE AREA	Staff's kitchen		Degree	Manager's office		Degree
	food storage	fridge, cupboards	10	doing office work	office desk, chair, communication & computer equipment	10
security	lockable doors	9	security	lockable doors	9	
washing dishes	sink 60cm, dish washer	8	storage	cabintes, shelves	8	
cooking	hood 60cm, oven 60cm, hob, m/w	7	natural light / fresh air	window (not accessible from the street)	7	
preparing food	countertop 90cm	6				
cutlery & dinnerware storage	cupboards, drawers	5				
eating	dining table with 4-6 chairs	4				
natural light / fresh air / natural ventilation	window (not accessible from the street)	3				
next to storage room		Total: 15m2	Min. size:8m2		Total: 8m2	

ADMINISTRATIVE AREA	Staff's office		Degree	Meeting room		Degree
	doing office work	office desk, chair, communication & computer equipment	10	attending a meeting	meeting table & chairs for 10 people, screen projector, computer equipment	10
security	lockable doors	9	natural light / fresh air	window (not accessible from the street)	8	
storage	cabintes, shelves	8				
natural light / fresh air	window (not accessible from the street)	7				
		Total: 15m2			Total: 15m2	

ADMINISTRATIVE AREA	Security office		Degree	Reception area		Degree
	doing office work	office desk, chairs, specialised facilities and equipment	10	doing admin work	reception desk, communication and computer facilities	10
visual access to the entrance		9	visual access to the entrance		9	
visual access to the street	window	8	security	lockable doors	8	
security	lockable doors	7	welcoming new residents	seating arrangements in entrance area, water cooler	7	
natural light / fresh air	window	6	storage	cabintes	6	
			natural light / fresh air	window	5	
adjacent to entrance area		Total: 10m2	adjacent to entrance area		Total: 10m2	

ADMINISTRATIVE AREA	Storage room		Degree	Loading area		Degree
	storage of supplies	cabintes / shelves	10	access to the street		10
security	lockable doors	9	security	lockable doors	9	
storage of fresh & dry food	cupboards, shelving units, fridge, freezer	8				
adjacent to loading area		Total: 15m2	adjacent to storage area		Total: 5m2	

Appendix 3. Adjacency Network B

216 21	BEDROOM	LAUNDRY ROOM	LAUNDRY ROOM (STAFF)	KITCHEN	DINING ROOM	LIVING ROOM	TV/CINEMA ROOM	FITNESS AREA	WC 1	GARDEN	COMPUTER TRAINING ROOM	EDUCATIONAL TRAINING ROOM	MEETING ROOM	LIBRARY	WC 2
BEDROOMS		X	X	X											
LAUNDRY ROOM	X		X												
LAUNDRY ROOM (STAFF)	X	X													
KITCHEN	X				X										
DINING ROOM				X						X					
LIVING ROOM							X		X	X				X	
TV/CINEMA ROOM						X									
FITNESS AREA										X					
WC 1						X									
GARDEN					X	X		X							
COMPUTER TRAINING ROOM												X		X	X
EDUCATIONAL TRAINING ROOM											X			X	X
MEETING ROOM											X	X			X
LIBRARY						X					X	X			X
WC 2											X	X	X	X	
MEDICAL CARE ROOM															
NURSE'S OFFICE															
COUNSELLING ROOM										X					
GROUP MEETINGS ROOM															
ARTS & CRAFTS ROOM										X					
ART & MUSIC THERAPY ROOM										X					
WC 3															
STAFF'S BEDROOMS															
STAFF'S WC															
STAFF'S KITCHEN															
MANAGER'S OFFICE															
STAFF OFFICE															
STAFF MEETING ROOM															
SECURITY OFFICE															
RECEPTION AREA															
STORAGE ROOM				X											
LOADING AREA															

X & colour = which rooms must be connected to each other  
X = which rooms must be close to each other

Appendix 4. Adjacency Network B – Connections

216 21	MEDICAL CARE ROOM	NURSE'S OFFICE	COUNSELLING ROOM	GROUP MEETING ROOM	ARTS & CRAFTS ROOM	ART & MUSIC THERAPY ROOM	WC 3	STAFF'S BEDROOM	STAFF'S W	STAFF'S KITCHEN	MANAGER'S OFFICE	STAFF OFFICE	STAFF MEETING ROOM	SECURITY OFFICE	RECEPTION AREA	STORAGE ROOM	LOADING AREA
BEDROOMS																	
LAUNDRY ROOM																	
LAUNDRY ROOM (STAFF)																	
KITCHEN																X	
DINING ROOM																	
LIVING ROOM																	
TV/CINEMA ROOM																	
FITNESS AREA																	
WC 1																	
GARDEN			X		X	X											
COMPUTER TRAINING ROOM																	
EDUCATIONAL TRAINING ROOM																	
MEETING ROOM																	
LIBRARY																	
WC 2																	
MEDICAL CARE ROOM		X					X										
NURSE'S OFFICE	X		X														
COUNSELLING ROOM		X															
GROUP MEETINGS ROOM					X	X	X										
ARTS & CRAFTS ROOM				X	X	X	X										
ART & MUSIC THERAPY ROOM				X	X	X	X										
WC 3	X			X	X	X											
STAFF'S BEDROOMS										X							
STAFF'S WC											X	X	X				
STAFF'S KITCHEN								X			X	X	X			X	
MANAGER'S OFFICE									X		X	X	X				
STAFF OFFICE									X	X	X	X	X		X		
STAFF MEETING ROOM									X	X	X	X	X				
SECURITY OFFICE															X		
RECEPTION AREA																	
STORAGE ROOM										X				X			X
LOADING AREA																X	X

X & colour = which rooms must be connected to each other  
X = which rooms must be close to each other



CONNECTIONS	ITERATIONS 300	ITERATIONS 400	ITERATIONS 500	ITERATIONS 600	ITERATIONS 700	ITERATIONS 800	ITERATIONS 900
KITCHEN-DINING ROOM	X	X		X	X	X	
DINING ROOM-GARDEN			X	X	X		
LIVING ROOM-GARDEN	X		X	X	X	X	X
FITNESS AREA-GARDEN	X	X			X	X	X
NURSE'S OFFICE-MEDICAL CARE ROOM	X	X	X	X	X	X	X
COUNSELLING ROOM-GARDEN	X	X		X	X	X	
ARTS & CRAFTS ROOM-GARDEN	X	X	X	X	X	X	X
ART & MUSIC THERAPY ROOM-GARDEN	X	X	X	X	X	X	X
STORAGE ROOM-LOADING AREA	X		X	X	X	X	
x: connection achieved							
x: connection achieved with minor adjustment							