Refurbishment of New Belgrade “Mass Housing” Envelope:

Evaluating the Potential of Daylight with Shading Integrated Adjustable Facade

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By

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Preface

Preface, acknowledgements.....

S. M. Mizanur Rahman
Detmold, July 2018

I dedicated the thesis to my daughters!
Meghmonjree Rahman
Deeptoamborie Rahman

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I thankful to my supervisor Prof. Dr.-Ing. Uta Pottgiesser whose inspiration and very special guideline let the thesis happened in such extent.

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Declearation

I hereby declare that this thesis paper titled **'Refurbishment of New Belgrade "Mass Housing" Envelope: Evaluating the Potential of Daylight with Shading Integrated Adjustable Facade '** submitted by me in partial fulfillment for the fourth semester of **International Facade Design and Construction (IFDC)** course of Hochschule Ostwestfalen Lippe, University of applied Sciences, Detmold, Germany; is a record of my own work. The matter embodied in this report has not been submitted for the award of any other degree or diploma.

Author

S. M. Mizanur Rahman

Certificate

This is to certify that S. M. Mizanur Rahman been allotted the thesis topic **'Refurbishment of New Belgrade "Mass Housing" Envelope: Evaluating the Potential of Daylight with Shading Integrated Adjustable Facade'** for his master thesis project as partial fulfillment of fourth semester examination for Master of **International Facade Design and Construction (IFDC)** course of Hochschule Ostwestfalen Lippe, University of Applied Sciences, Detmold, Germany.

This is further certified that he has completed this project work in one semester under my guidance and supervision.

Anica Dragutinovic, M. Arch.

This thesis project has been accepted.

1st Supervisor________________________

2nd Supervisor______________________

Summary

Many existing buildings worldwide date from the second half of 20th century require an improvement of their building envelopes related to energy efficiency but also in terms of general maintenance and refurbishment. While many refurbishment approaches deal with the improvement of insulation of opaque and transparent areas; this thesis will investigate the potentials of daylight by applying a shading integrated into an adjustable facade for the improvement of indoor comfort, spatial quality and energy efficiency.

The modernist building blocks in New Belgrade constructed from 1950s to 1970s which are under study for refurbishment will be considered as research exemplar for the simulation. In addition, it will be studied what impact of the possible improvements will have towards the architectural appearance of the building blocks and for the ensemble.

To do so, the thesis will start with an analysis of typical materials and systems used in the building blocks of New Belgrade. Daylight factor and solar energy will be simulated for the exemplar building's existing condition. A shading integrated adjustable facade system and its variants will be applied for the refurbishment of the building. The condition will be simulated and be compared with the previous results.

This thesis will investigate architectural design variants with SIAF and the potential of adaptability and personalization taking into the consideration the iconic character of the New Belgrade "Mass Housing" and eventually other examples of similar character of other countries.

Contents

1. Research Framework

1.1. Background

New Belgrade mega blocks were built in the second half of the 20th century as a modernist residential neighborhood, following the concept of a socially owned housing. Since the construction, the New Belgrade mega blocks went through different levels of transformation, especially in terms of housing policies and ownership. However, they did not went through any physical upgrade since construction. Therefore, the blocks are showing some sort of lack in accordance of user's demand, due to the lack of maintenance and upgrade referring Figure 2(Glavički M, Đorđević, A 1962). The building blocks were the first where new pre-stressed concrete structure known as IMS (named after the Institute for testing of materials-IMS in Belgrade, where it had been developed) has been experimented and evaluated. During the time, the housing mega blocks were facing social-economic evaluation of the country. [2] Consequently the building blocks impact on people's lifestyle and behavioral pattern. Thus New Belgrade modernist residential mega blocks conceived people's emotion and value.

Figure 1: Regulation Plan of the Area of New Belgrade Municipality (Glavički M, Đorđević, A 1962), adopted from [1], accessed on 24 April 2018.

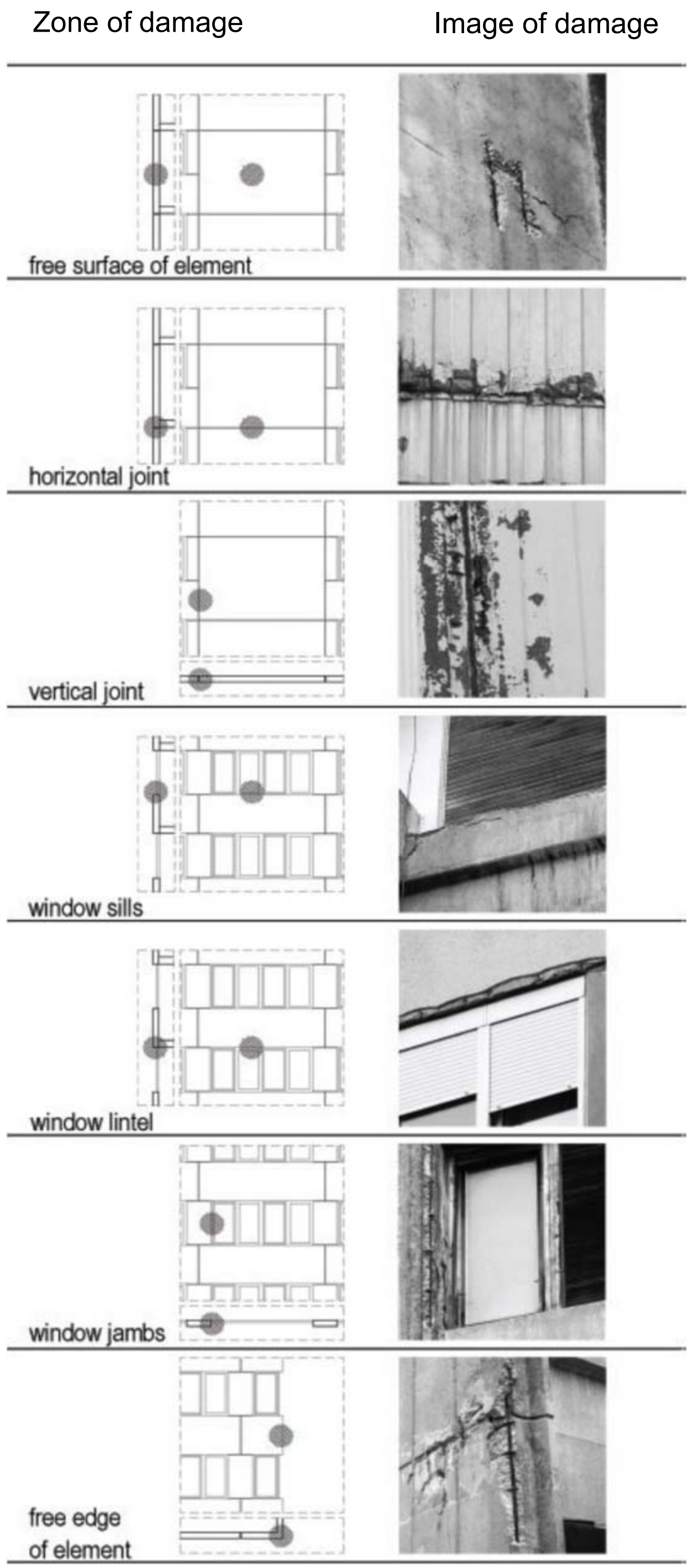


Figure 2: Mapping of possible damage positions (Macut, N & Radivojević, A 2016), adopted from [15], accessed on 24 April 2018.

Thermal condition in indoor environment was the principle component of human comfort. During times it is proven that passive or active design of HVAC is not sufficient to ensure human comfort in indoor environment especially in residential buildings. Daylight and view influence positively towards people's feel of comfort. Noise, light, air quality and flow, humidity and temperature is widely considered factors to control indoor environment quality. [14] However, people reflect over these factors in two ways. One is physically and another is psychologically; as comfort itself is a matter of experience and perception. Nevertheless, daylight and view towards outside has great impact on people's psychology. [6] As comfort is directly related to human personal experience; therefore, change of experience causes the change of comfort, [7] though there are upper and lower ranges of factors those are related to survival issues. Use of daylight is an art of negotiation between daylight condition and user comfort. Variability of daylight is one of the most favorable advantage of using daylight. Variation influences human psychology positively to make a ridged space interesting. [13] Users may well be satisfied with indoor daylight conditions even though they do not comply with prevalent lighting recommendations, and vice versa. Natural light has both visual and non-visual effects, it can cause glare and influence thermal comfort, it regulates our sleep/wake cycles and it has a significant influence on our appreciation of the quality and attractiveness of a space. [6], [7]

Reinforced Cement Concrete has been invented around one century ago. It is dominating in building material field till date. As concrete is called as artificial sedimentary rock, its usual lifetime is considered as around a hundred year. The buildings with reinforced concrete can be used around seventy five years.[8] However, in this long range of period, inhabitant changes, socio economic conditions changes, invention changes, lifestyle and taste changes, crisis changes, demand also changes. Therefore, building needs to reform. Moreover, Concrete in the 1950-60 was often badly executed and shows a lot of damages; such as not enough concrete coverage, bad mixtures and so on. This called for maintenance or refurbishment of the construction. Demolition of an existing building and rebuild with a contemporary design may be a solution but an existing building apprehends some societal variables. Economy may not be always the prime issue. However, refurbishment usually cost less than rebuilding. This is because all of the components of the building does not annihilate at a time. [8] Therefore, possibility of refurbishment needs to be considered before rebuilt. New Belgrade mega-blocks need to be refurbished due to all of the changed criterions. In addition, the whole neighborhood is to be preserved and under consideration to be listed officially as heritage. This duality creates the scope to do the thesis. The thesis will search for the possibilities to increase user comfort regarding the adaptation of daylight through a facade system whose new architectural appearances will not conflict people's emotion and the architectural and heritage values.

1.2 Problem statement

After the Second World War New Belgrade emerged on the empty terrain of the west bank of Sava River aiming to become a center of administration, culture and economy of Yugoslavia. The city was however gradually built in 1960s and 1970s as a city of housing mega blocks. It is a specific realization that is combining the concepts of modernism though socialism. [1] The changed socio-political conditions in Yugoslavia in the 1990s led to the privatization of the previously socially owned housing and further transformation of the urban pattern of New Belgrade. While New Belgrade was becoming a popular business district, its housing blocks became one of the most popular and the most expensive residential areas in Belgrade as well, despite their physical condition and obsolescence. Thus their technical and functional obsolescence need to be addressed. The contemporary issues about sustainability need to adopt to this building. Their present conditions urges renovation. [9]

Moreover, New Belgrade blocks have a unique character in terms of adaptation of the modernist concepts to the specific context. Thus they represent the most important architectural heritage of the twentieth century in Belgrade and also have a particular significance in international context. [9] Therefore, this residential blocks should be under consideration of preservation in some way. The master thesis investigate on the requirements for refurbishment on one hand, but also on the values of the buildings and preservation demands focusing on the specific case study: New Belgrade Block 23, Building 6.

1.3 Objective

The aim of this thesis is to investigate the potentials of daylight with shading integrated adjustable facade for the improvement of indoor comfort, spatial quality and energy efficiency.

This thesis will start with an analysis of typical materials and system used in the buildings of New Belgrade. Daylight factor and thermal transmittance will be simulated for the exemplar building's existing condition. A shading integrated adjustable facade system and its variants need to design and develop. It will be applied for the refurbishment of the exemplar building. The condition will be simulated and the result will be compared with the result of present condition.

This thesis will investigate architectural design variants and the potential of adaptability and personalization in the consideration of iconic character of the New Belgrade mega blocks and eventually other examples of similar character of other countries.

1.3.1 Sub-objectives

- Analyze the present situation of the exemplar building no:06, Block 23 of New Belgrade regarding its structure, cladding and glazing to find out the potentials for refurbishment
- Simulate the present situation in terms of daylight and thermal transmittance
- Design a façade system suitable for the refurbishment; considering the architectural values of the original design
- Simulate the proposed situation in terms of Daylight and thermal transmittance and compare the result with the result of present situation
- Create architectural appearance showing the potential of adaptability and personalization with the design variants
- Receive the feedback of the compared simulated data and the architectural appearance from the present users of the exemplar building
- Indicate the solution for other examples of similar character of other countries.

Final outcome will be a facade system appropriate for the refurbishment solution of the New Belgrade housing mega blocks.

1.4 Approach and methodology

1.4.1 Literature review

To understand the refurbishment potential for the residential typology and the specific exemplar building; to research on the indoor comfort and daylight in residential buildings, current practices for improvement of it; to find out the potential of shading integrated adjustable facade. Furthermore, the research on the case study, current condition of the building and architectural values of the original design will be done. The literature review will show results of this research.

1.4.2 Data analysis

It is required to analyze the design data to find out the construction method, structural system and the capability of structure. To design a facade system it is needed to understand the climate of the location. For this regards, it is important to analyze the climatic data of New Belgrade, Serbia.

1.4.3 Dynamic calculation (simulation)

The present condition of the building will be simulated in terms of daylight condition and thermal transmittance in winter time. ‘Autodesk Revit’ will be used to simulate the situations. In addition, the software will be used to simulate the conditions with the proposed facade system in order to compare both the results.

1.4.4 Design

To test and offer a refurbishment solution the facade redesign is needed. Moreover, the facade system will be considered adaptability and personalization to fit the various user’s tastes and requirements of view and daylight. In order to suite with the iconic character of the New Belgrade housing blocks the design of facade system will emphasize that character and the system will be more convincing to design a smart but nearly invisible solution.

1.4.5 User’s feedback

Architectural appearance for the new solution to be generated in 3D Max of the exemplar building. The compared simulation result along with the architectural appearance will be exposed to the existing users. A questionnaire will be prepared to get the feedback from the existing uses. The summary of feedback will be add in this thesis.

1.5 Planning and organization

The following scheme presents the work flow and the research methodology:

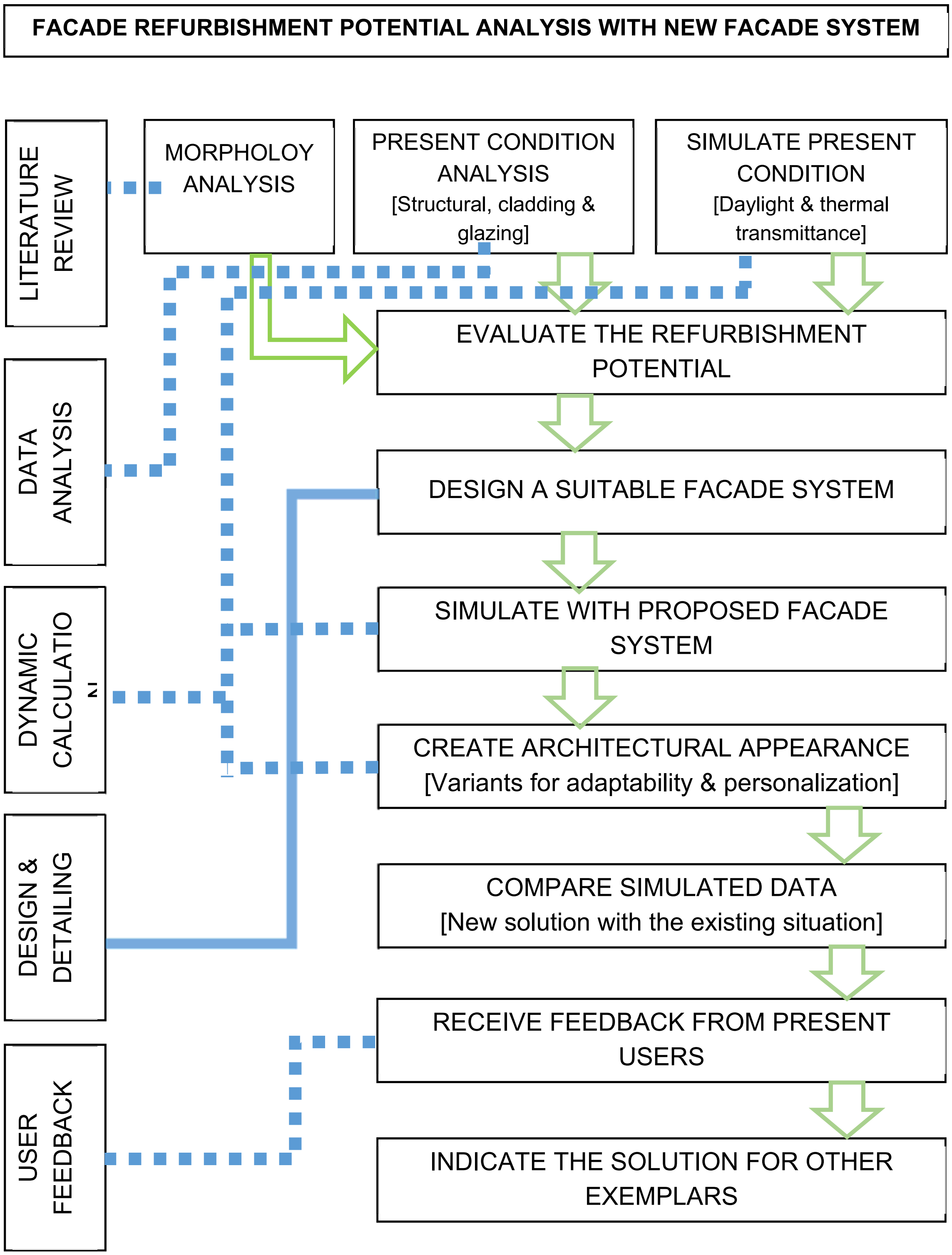


Figure 3: Schematic Diagram of work flow and methodology, (Rahman, SMM 2018).

The time frame and organization is given below as Gantt chart.

	Task Name	Week	01	02	03	04	05	06	07	08	09	10	**DL**	11	12
01	Chapter- One Introduction														
02	Chapter - Two Exemplar Analysis														
03	Chapter - Three Proposed System Analysis														
04	Chapter – Four Architectural Appearance and Materiality														
05	Chapter – Five Comparison and Feedback														
06	Chapter-Six Transferability of Results														
07	Referencing, Finalizing and Submission												10. 07		
08	Preparation & presentation														23. 07

Figure 4: Time Frame and Organization Gantt chart, (Rahman, SMM 2018).

1.5 Relevance

1.6.1 Societal relevance

The New Belgrade housing blocks urge for refurbishment due to lack of maintenance, different user's needs and for the age of the building. The contemporary issues of sustainability are also pushing the building for the refurbishment. Energy issue is the principle concern for sustainability. However, user comfort issues cannot be ignored. The buildings had important socio-cultural, political and architectural significance in the last half a century. Thus it creates a historical value of its own to the people of the city and to the globe. The thesis will look for a facade solution considering the solar energy and daylight situation. The solution will also justify the user comfort through adaptability and personalization reflecting the heritage value the building earned from the society. The design of facade system will emphasize the iconic character and the system will be more convincing to design a smart but nearly invisible solution.

1.6.2 Scientific relevance

Shading device is an essential part of modern facade solution. Though it is an integrated part of vernacular houses all over the world especially in tropical and sub tropic climate. However, in cold climatic region controlling sun is a vital function of shading device. Mechanized shading device is used for managing direct sunray transmission into the interior space. Thus the traditional principles became more sophisticate, mechanized and later atomized. Nevertheless, all of these devices hinder the view of the users of the interior spaces. The 'Shading Integrated Adjustable Facade' will hinder the least while shading the sun. Considering that, the facade system will affect positively on the fundamental quality of shading system and also considering that, this system will have a vast potential of personalization in terms of architectural appearance and in terms of adaptability; thus it will create interest in the field of facade technology for its further development and customization.

1.6.3 Projected innovation

The proposed SIAF system will hinder the view least while shading the sun. View is a sophisticate quality of architectural space. As this system will enhance this quality to the interior environment, it will supposed to be popular to the facade industry. Thus it will create the opportunity to invent new facade profiles and other mechanical components to support this system. Nevertheless, every system has its scope of further development.

1.6.4 Embedding in research programs and relationship with other research projects

This thesis follows the scope of the ongoing PhD research of Anica Dragutinovic, titled "Developing an Evaluation Framework and Re-Design Strategies for Modernist Housing Blocks in New Belgrade" while focusing on the potentials of shading integrated adjustable facade to be applied on the specific case study and considering the adaptability and personalization of the proposed facade solution.

2. Literature review

2.1 Does Building 6 of Block 23 need to be refurbished?

A city with the idea of social housing which arranged the residential complex around small neighborhood center with shops, services, center of elementary education and health facilities is the city of New Belgrade. Prokopljevic (2015) has describe and urged not to through the concrete blocks of New Belgrade. He mainly focused on the social pattern of the community. He addressed the issues of social housing in the context of a socialist city having in mind the differences and similarities between social housing as a concept and as an organization in different economic systems in the context of Yugoslavia highlighting the interdependence of social housing neighborhoods and nature of their insertion in the collective urban imaginary. [12] He argued that, 'This "new urban" had different forms and typologies in New Belgrade, not always legal and not always pleasant, following the relatively negative image of the city inherited from the previous epoch. The transition period, convoluted in Yugoslavia by the destruction of the common state, brought the final destruction of the public image and the "criminalization" of public housing blocks.' The main complaints were oriented towards the lack of public spaces for socio-cultural activities, the super-human urban scale of New Belgrade, the inflexibility of internal and external building structures, housing shortage, space and limitations for improving the dwelling according to individual criteria. The problems were intensified by the altered social structure from mass immigration to the capital in parallel with the industrialization and massive construction of residential neighborhoods. On the other hand Jovanovich (2017) argue that without the integration of industrialization and urban planning, New Belgrade would not have been possible to build, as we know it today. Similarly, it is this, in many ways intangible heritage that needs to be emphasized. [1] She found the mass housing as mass heritage for two main reasons. The first is the scale and numbers of it, as something quite different from the heritage previously known and the second is due to its emergence on a vast scale in a short period. She concludes with a question 'Mass Housing as (Mass) Heritage?' [1]

2.2 Is it possible to refurbish the Building 6?

Dragutinovic et al. (2018) investigated the metamorphosis of New Belgrade, and analyzed the housing blocks to present their values and to contribute to the preservation issues. They also highlighted the current condition and the needs to be adapted for the block 23. They studied to find out the adaptive capacity of applied prefabricated IMS (Institute for testing of materials) systems. They found that the flexibility and modularity of the IMS system can provide adaptability of the structures to today's requirements. [2] Whereas Nikolic (2018) proposed an IBM (Industrialized Building Model) that provides firm description of massive housing buildings, the requirements for information that to be provided for approving refurbishment processes. He considered some housing blocks in New Belgrade as case study. There he showed the technical scope of refurbishment of the IMS building technology with which the Building 6 of block 23 is made of. [3]

2.3 Daylight, is it valuable!

Andersen (2018) referred to the British neuroscientist Russell Foster who advises us to take a 'photon shower' every morning to adapt our biological clock to the rhythm of nature. In former times, people used to work mainly during daylight hours, sleeping longer in winter than in summer. Perhaps, this would be a more natural way of life that would be better for us. In any case, we risk a feeling of permanent jet lag unless we adapt our rhythm of life to the rhythm of the sun and recognize its signals. [13] 'Daylighting design is an art of negotiation' as said by Schoof (2016). The negotiation is in between the specific daylight conditions on a given site and the comfort requirements of the building users. It is the negotiation between qualitative design goals and measurable physical quantities and also between the different factors on which daylight influences human being. Natural light has both visual and non-visual effects. It can cause glare and it can influence thermal comfort. Daylight regulates our sleep and wake cycles. It has a significant influence on our appreciation of the quality and attractiveness of a space. [7]

Daylight is an integral part of Architecture. It is not possible to create an Architecture without daylight. Designing of daylighting is nevertheless one of the most sophisticate part of architectural design process. This is because, daylight influence on human physical activity as well as on human emotion. [7] To find out the optimum position of daylight factor is crucial and critical. Daylight makes architectural space glorious. It is an important factor to design.

2.4 Is SIAF new?

Shading Integrated Adjustable Facade (SIAF) is a system where the skin consists of two parts. The lower portion is clear glass up to over human eye level and the upper portion is usually opaque up to overhead ceiling. This portion will act as shading which is usually opaque but the material may be translucent or even transparent. The SIAF is able to move outward and inward respecting the sun angle. User can adjust the facade according to their need of sun though they will not lose their view noticeably.

While searching for adjustable or adaptive façade, lot of research papers and examples are available in internet. The extent it has been searched and studied it is found that adaptive facades are mainly working on shading systems. While it is required to shade the building the view also hindered or omitted. However, Csoke (2011) wrote about adaptive facade in her Master Dissertation book. Where she proposed a facade system whose shading is integrated with the facade and can be adjusted only outward from vertical position referring figure: 5 Csoke (2011). [14] This system has the closest relation with SIAF. SIAF can be moved on both inward and outward. Thus SIAF has the better adjustable option over the other one. In addition, SIAF can be used as double skin or as single skin. SIAF is comparatively simple and can be produce in less technological involvement. Therefore, it can be said that SIAF has some novel potentials.

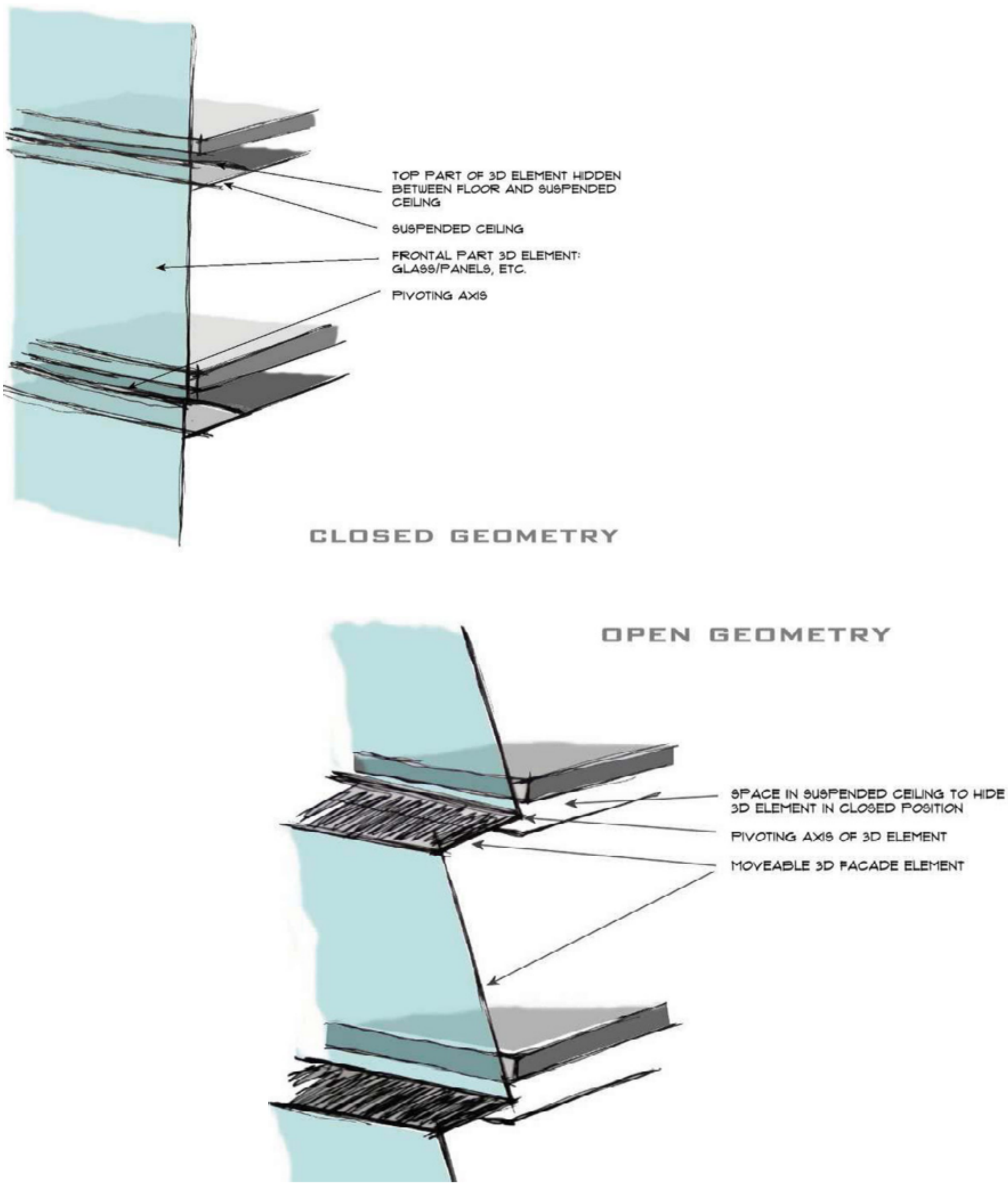


Figure 5: Schematic Diagram of Adaptive Facade, (Csoke, C 2011).

3. Exemplar analysis as status quo

3.1 Background

Modernism in Belgrade emerged after the end of First World War when the identity of the city´s architecture was quite heterogeneous. The first phase of modernism in Belgrade was marked by the Group of Architects of the Modern Movement GAMM. The first modernist realization in Belgrade, Zloković's House, was followed by different buildings, and within the housing typology mainly urban villas and apartment buildings. [2]

After the Second World War, the left bank of Sava River was set to become the new capital of the Yugoslavia. This is because, the left bank was a vacant land while the right side was already full and massively destructed in wartime. The political intention was to prove the will, power and knowledge of newly emerged socialist state. Nevertheless, the scarcity of housing played the core role to build the new city. New Belgrade was a swamp, hence no need to create 'Tabula Rasa' conditions in the Le Corbusian sense of the term, by tearing down the existing structures, as empty terrain was already there. Soon they stated the industrialization of housing construction as one of the country's priorities. Consequently planning institutions emerged so that, they would be able to absorb and deal with the enormous amount of work ahead of them. These processes took a decade to consolidate and coordinate among themselves those were all the necessary pre-conditions for the emergence of New Belgrade. [1]

Figure 6: (Glavički M, Đorđević, A 1962), The housing estate Tošin bunar of Block 7, New Belgrade, beginning of the 1960s. Source [1], accessed on 24 April 2018.

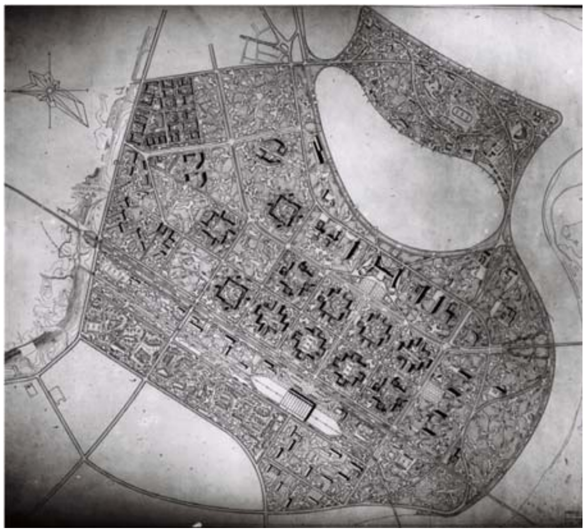



Figure 7: Layout of Central Zone; Figure 8: Federal Executive Council's unfinished building 1960s (Petričić, B 1962), source [1], accessed on 24 April 2018.

An open design competition awarded for the central zone of the New Belgrade which introduced the concept of blank map where a 'gabarit' or template of a block designed. Later this gabarit filled with function and details of the elevation. The construction process facilitate the application of prefabricated system through 'archetypal modernist structure'. More the city approached its center, more sophisticated technology and design was adopted. [1]

The block 23 of New Belgrade was constructed in 1973-76 according to the project of the three architects Aleksandar Stjepanovic, Bozidar Jankovic and Branislav Karadzic. It consists of 2100 flats in eight buildings, four high-rise buildings of 23 storied, two linear eleven storied buildings and two five storied buildings in association with a school, kindergarten, a community center, playground and green open space. All the eight buildings are constructed in two structural systems, one is IMS and another type is Panelized. Both panelized and IMS systems were developed with the same aims; efficient construction, flexibility in spatial organization, variety in flat types, openness for different envelope design, however their performances in these terms varies. [9]

The envelope design of the building 6, one of the linear buildings that was applying IMS system, will be further analyzed.

3.2 Exemplar building: building 6

3.2.1 General analysis

The building 6, 280 meters long, consists of 622 flats. It is an eleven story building. The ground floor is for mainly circulation and lobby of lift and staircase. Except the lift and staircase it has no enclosure. The ground floor is mainly columnated shaded space. No apartment is placed in ground floor, Figure 9: (Jadranka Ahlgren 2016) eye level view of Building 6 Block 23, New Belgrade. The building is divided structurally into seven lamellas, Figure 10: (Rahman, SMM 2018) Typical floor plan of Building 6.

Figure 9: Eye level view of Building 6 Block 23 New Belgrade, columnated space in ground floor (Jadranka Ahlgren 2016).

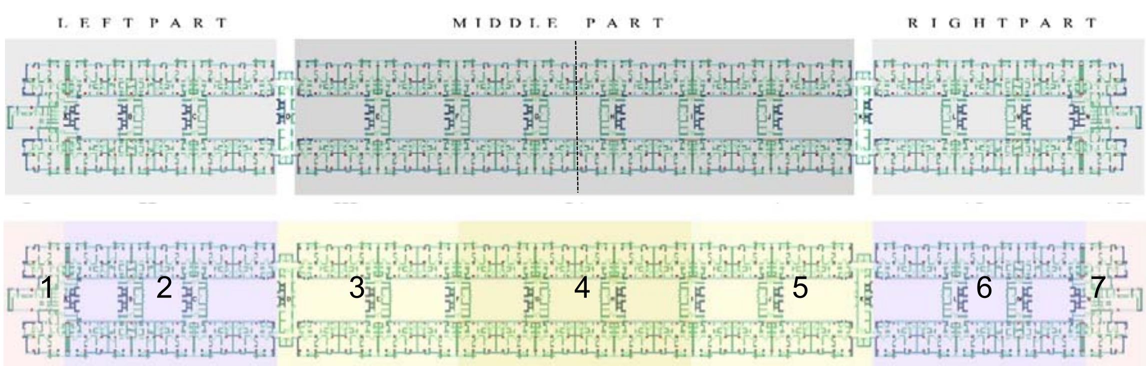


Figure 10: Typical floor plan of Building 6. Showing the symmetry on top and the lamellas on below (Rahman, SMM 2018).

The segments are mainly because of structural purpose. However, it has been done in such a way that architectural functionality did not hinder much. The internal arrangement of apartments of lamella 2 to 6 are almost same in layout character, the linearity of apartments has been adjusted only. The apartment arrangement within the building is uniquely characterized as 'Double Tract' layout pattern. Therefore, the apartment arrangement is symmetric along its longitudinal axis. Moreover, the building 6 is symmetric along its cross section also, resulting the segment 1 and segment 7 are symmetric, though in exterior appearance the building consists of three parts along length; Figure 11: (Jadranka Ahlgren 2016). Double tract layout unveil the scope to create courtyard in between tract. The tract is connected with fourteen vertical circulation bays with utility spaces. Thus it created thirteen courtyards those enabled double orientation of the flats. It gives the scope to design narrow and long flats, in addition flats within the same length with enlarged depth of the tracts. As a result, the flat is ample of natural light and huge ventilation possibilities across. This approach enhance the internal spatial quality. Due to its structural system the building got the possibility to set column to column windows. The windows are placed on a seal level of 30 cm, having the drop of 30 cm from the ceiling.

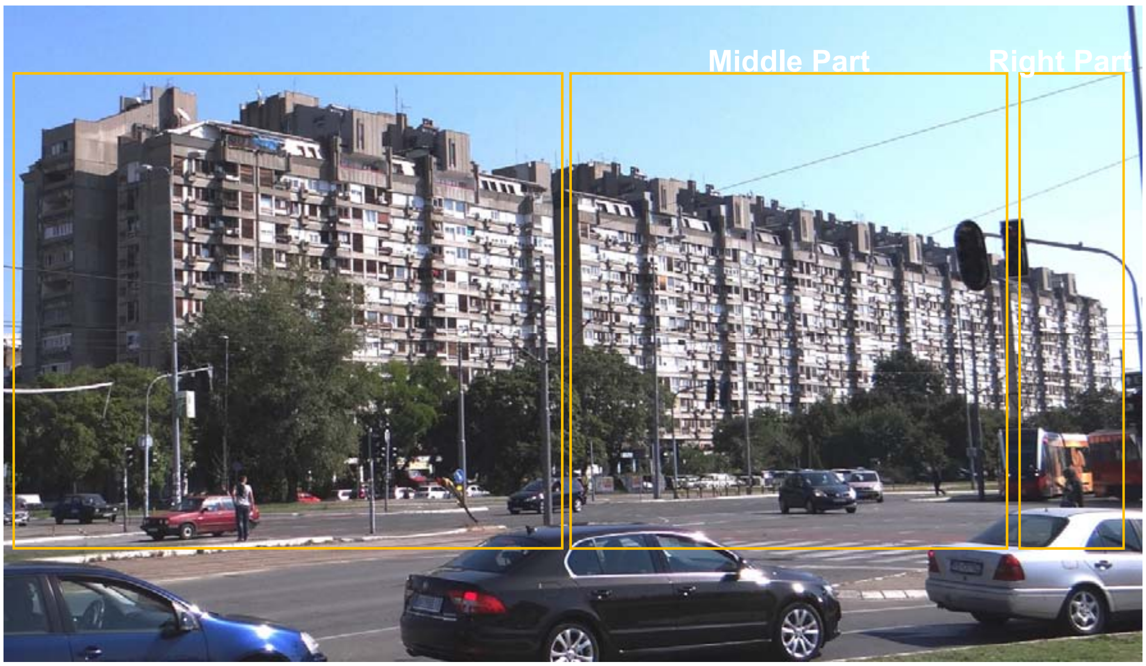


Figure 11: Building 6 Block 23 New Belgrade; exterior view from east, adopted from (Jadranka Ahlgren 2016).

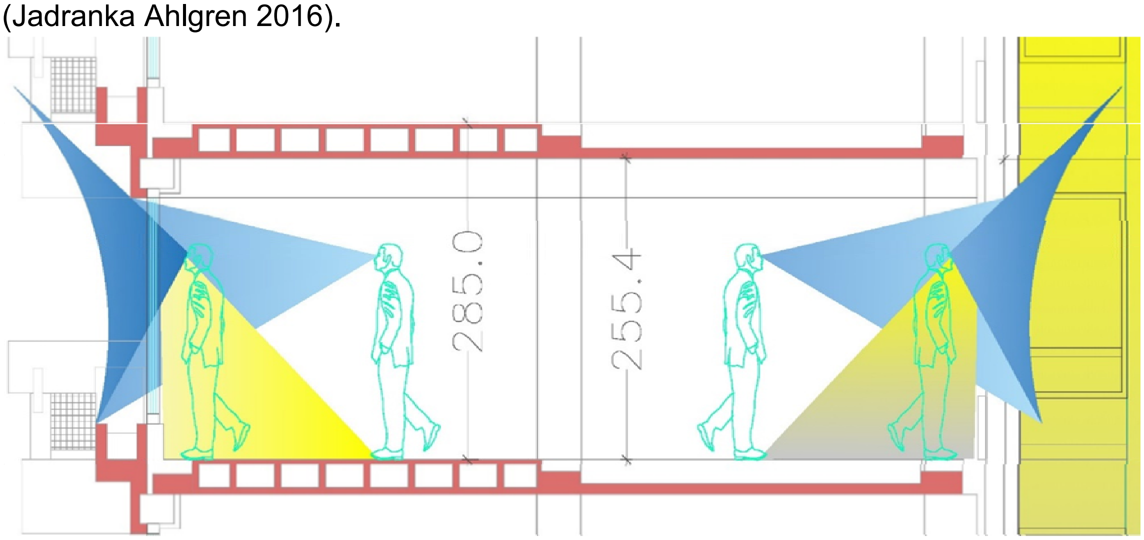


Figure 12: Cross section of apartment; daylight and view (Rahman, SMM 2018).

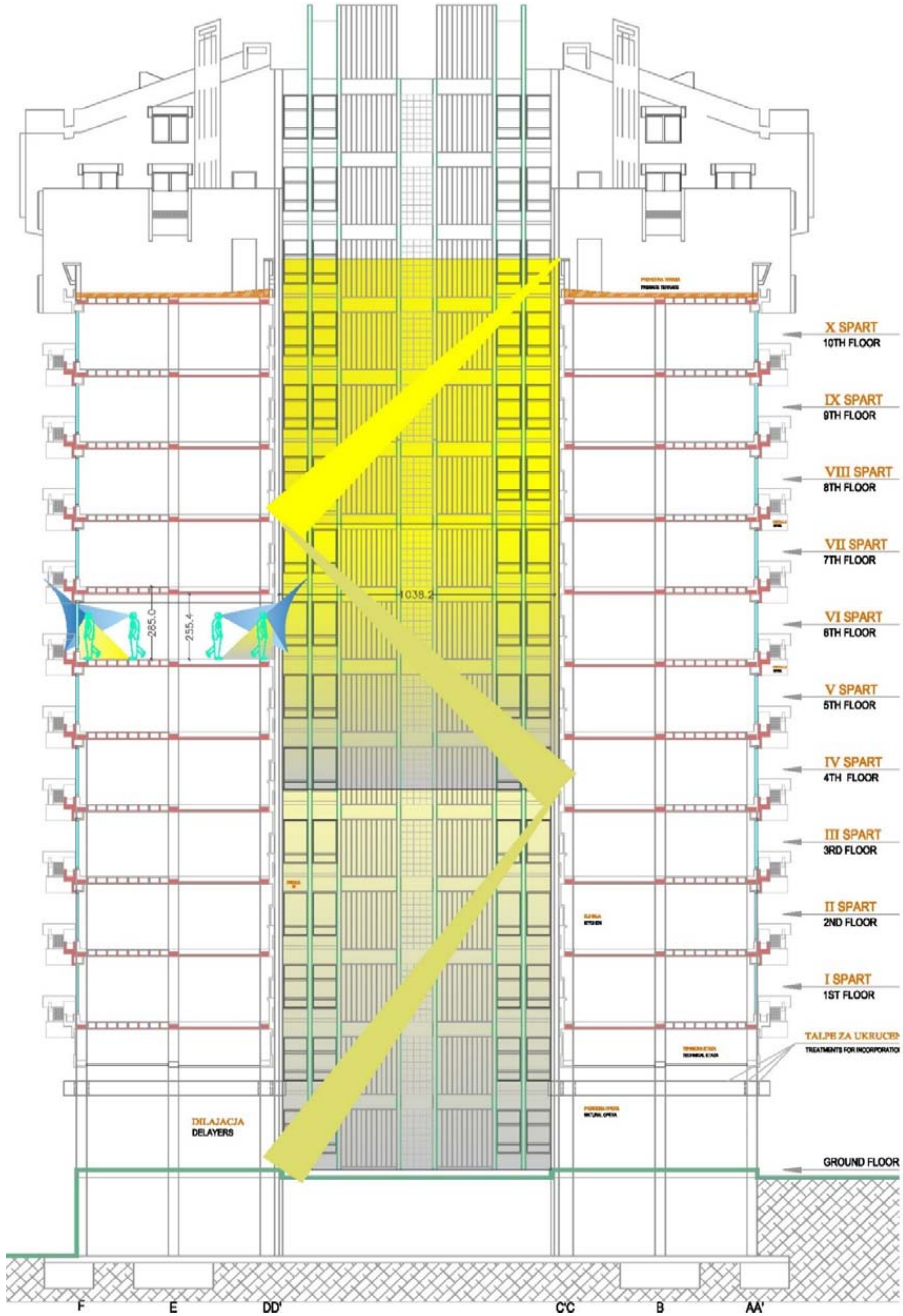


Figure 13: Cross section of Building 6; Diffused daylight through courtyard (Rahman, SMM 2018). Adopted from Anica Dragutinovic according to the original drawings from Historical Archive Belgrade.

Though the room clear height is 260 cm which is quite a bit less than a standard height room but big size windows overcome the limitation. The position and size of the window ensure sufficient daylight as well as views towards outside to confirm user comfort referring Figure 12: (Rahman, SMM 2018).

It is necessary to mention about the scale of the courtyard. The width verses height ratio of the courtyard is around 3:1. This ratio of courtyard though does not ensure decent human scale from the ground or approach level, however it creates a very good intimate human scale from fourth level to the tenth level showed in the Figure 13: (Rahman, SMM 2018); Diffused daylight through courtyard. The courtyard ratio and size allow reflected sunlight entering into the apartment through the court faced windows very well. However, the first four level of apartments get insufficient reflected daylight. Therefore, they depend mainly on the daylight from outer facade window.

3.3 Structural analysis

The building 6 of block 23 is constructed in the system known as IMS. The skeleton system was developed by Prof. Branko Žeželj at the Institute for testing of materials-IMS in Belgrade. In the early 1950's, former Yugoslavia had a great problem of housing space deficit, which represented a challenge for the great constructor Branko Zezelj and his team. He along with Eng. Bosko Petrovic developed the skeleton system while applying a new building material named 'pre-stressed concrete'. The prefabricated concrete frame consists of columns, beams, floors slabs, shear walls and staircases. It offers a wide variety of different buildings produced out of relatively small number of typical elements. An important characteristic of the IMS Building Technology is that it represents an open system, which can accommodate various subsystems, differing in both technology and materials. [3]

3.3.1 Characteristics of IMS system

The IMS Institute of Belgrade describes in the 'IMS Building Technology' brochure (IMS Building Technology, n.d.) as it is low cost. It minimizes the use of steel and concrete, significantly reduces the construction time, it does not require high-tech equipment, increase building durability. All these characters impact on reducing cost in short term and in long term.

The IMS is a pre-stressed structure which dissipates kinetic energy caused by seismic activity or hurricanes. Perceptually it resists to earthquakes up to 9 degrees of Richter's scale. The IMS is a prefabricated system. Pre-fabricated elements can be produced regardless of weather, season and climate. The construction technique also impact on construction process on reduction of time.

In the IMS System, indigenous material and technique can be applied on facades, roofing and interior surfaces. It obtains energy efficiency as well as cost efficiency. Local human resource can be easily trained for producing prefabricated element and also for the construction process. As this system ensure long span, it enables flexible spatial solutions, greater space-planning capabilities and wide range of possibilities for building interior design. [10]

3.3.2 Assembly process of structural elements

When building foundations are done, with precisely left openings for anchors of prefabricated columns, multi-stories columns are positioned and fixed, with the help of braces, in vertical position. Temporary capitals already exists on columns on which floor structure elements such as floor slabs, edge beams and cantilever floor slabs are erected. Afterwards, floor slabs are made monolith with web post-tensioning using appropriate short cables. Joints between columns and floor slabs are filled in with adequate mortar and after its hardening, the entire floor plane is post-tensioned with cables into two orthogonal directions. After this action, braces fixing columns are released, supporting capitals are transported to another story level and the operation of floor slabs erection is repeated. [3]

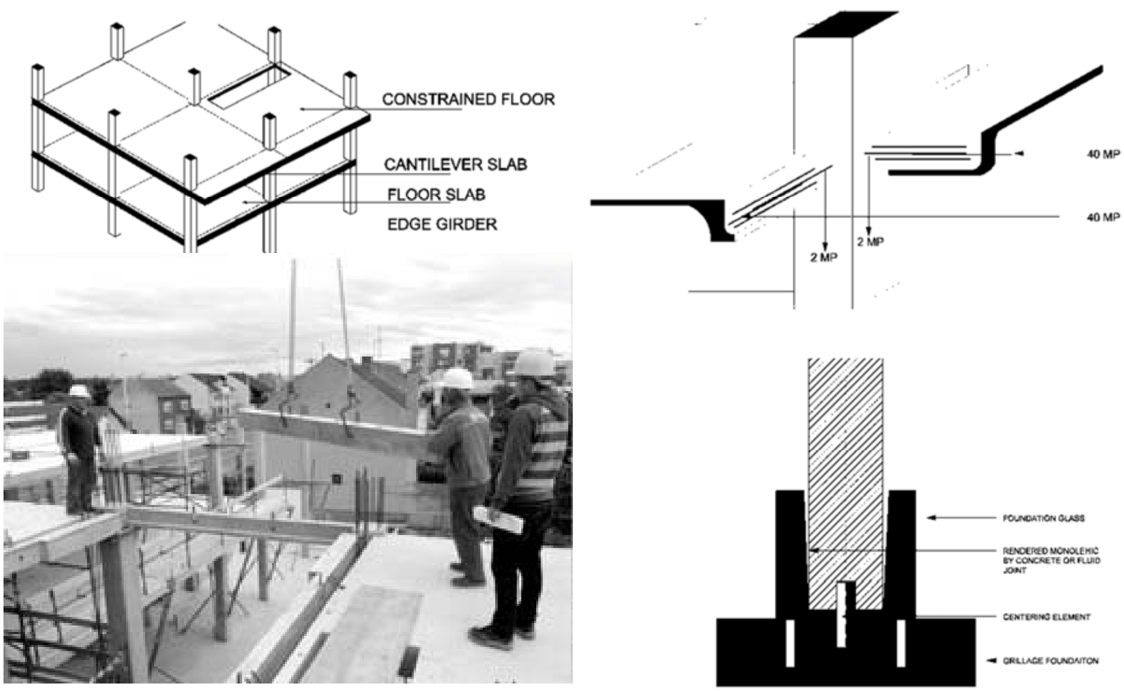


Figure 14: IMS system: (a) Skeleton fame consists in concrete column, pre-stressed beams, cantilever slab, edge rib; (b) Slab to column joint; (c) Top view of standard floor slab; (d) Column joining with foundation (Rahman, SMM 2018). Adopted from [3]

3.4 Refurbishment potential of the IMS

The construction of the building 6 in block 23 was following the IMS system, and therefore it applied IMS standardized components for the whole building: column, slab, edge girder, cantilever slab, stair, shear wall, roof slab, balcony railing, parapet and industrialized sanitary blocks all these component has been followed the IMS system.

3.4.1 Systematic Approach

The IMS structure is designed and built as an open systems' configuration model. All systems and components belong to integrated configuration model arranged according to the main building functions; such as load-bearing, enclosing, partitioning and servicing. Systematization of industrialized components into independent levels takes into account that different parts of the building have different life span and functional expectances, as well as different assembly procedures. The key aspects of sustainable retrofitting are in the housing ability to be dismantled where the systematization and the hierarchy support total configuration disassembly.

Main characteristics of Industrial Building Model (IBM) are the systems and components those are assembled into independent functional and technical levels. As shown in the figure 15: (Rahman, SMM 2018); the load-bearing structure is designed and built as IBM. Isolation of IMS support skeleton assembly allows a number of different in-fills distributions in the future use of IBM. It has the possibility to change the surface of the floor plan, either by additional construction or changes in the boundaries of units out of the support limits. The connections between removable parts and load-bearing structure are mechanical joints. The positioning of services as independent system provides easy access and HVAC system upgrading. IMS housing is designed with or without cantilever slabs with variable main module to generate diversity in the layouts. The building core contains all important installations. Such as, central communications and services. Those are stairs, bathrooms, cleaning rooms and toilets. In that way all the apartments may have two-side orientations. This kind of solution supports the initiative to exploit the maximum of the living space. [10], [11]

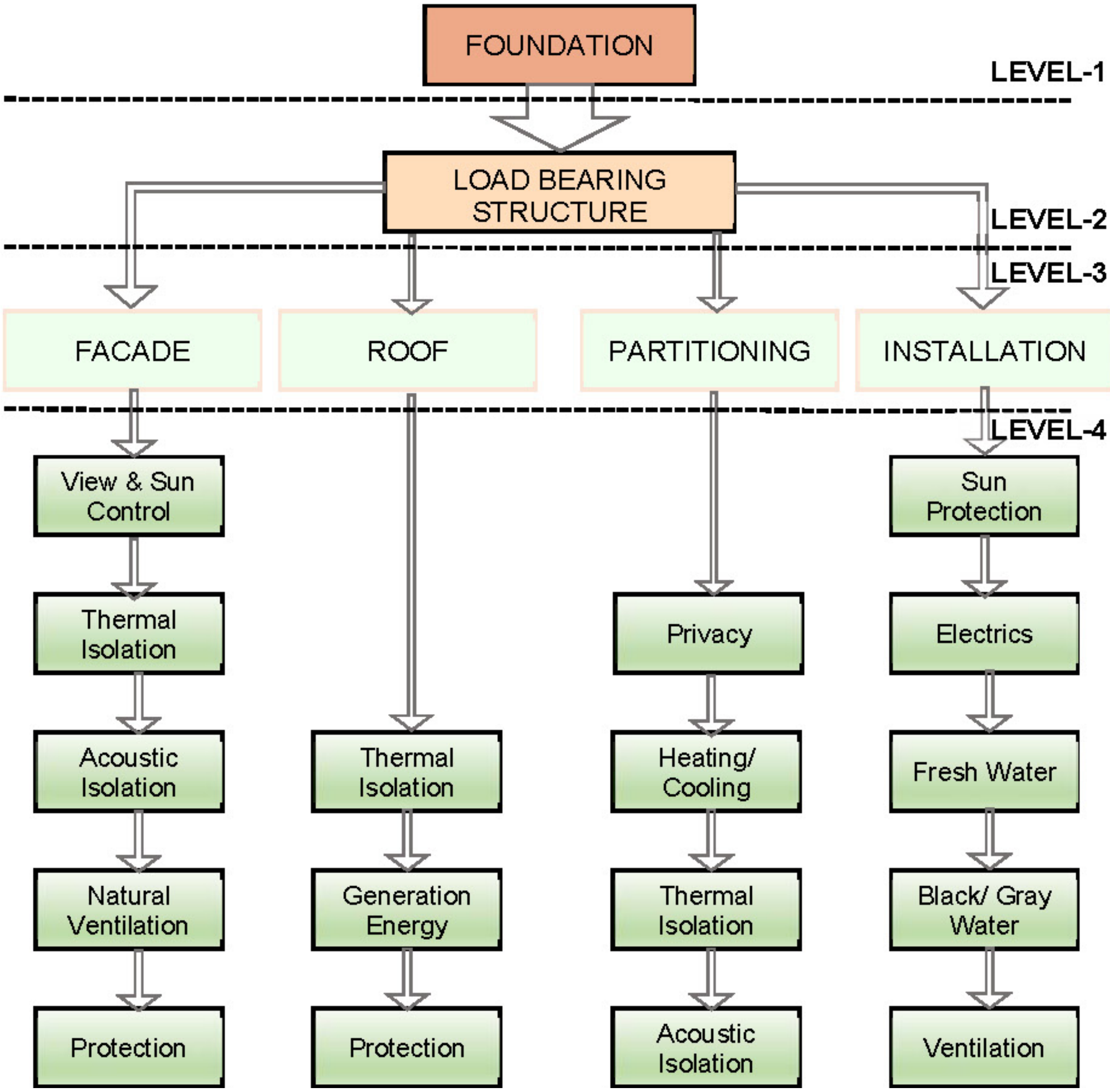


Figure 15: Schematic view for systematic approach according to independent functional and technical levels, IBM massive structure hierarchy (Rahman, SMM 2018). Adopted from [11]

Graph Model (GM) diagram, as shown in figure 16: (Rahman, SMM 2018) describes the IBM by elements as a diagram of relations. The elements are components, components assemblies, subsystems and systems. Graph model represents relations and dependency condition in massive structure.

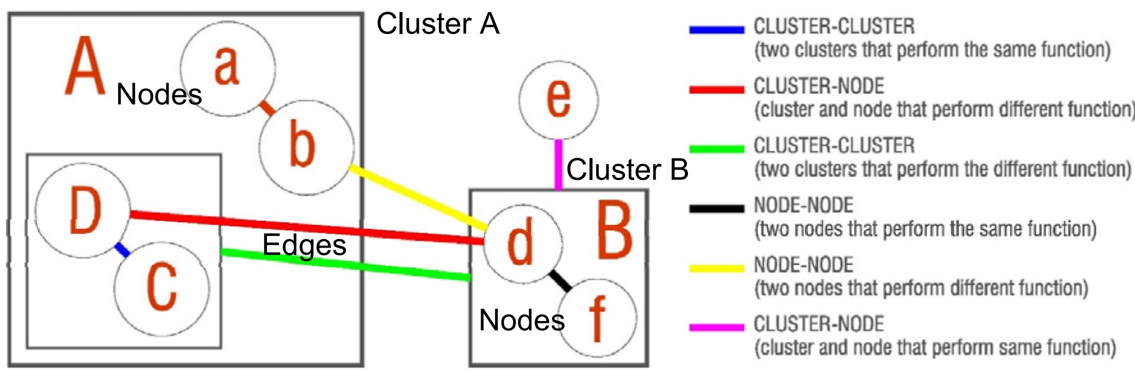


Figure 16: Graph Model defined by Node, Edge and Cluster (Rahman, SMM 2018). Adopted from [11]

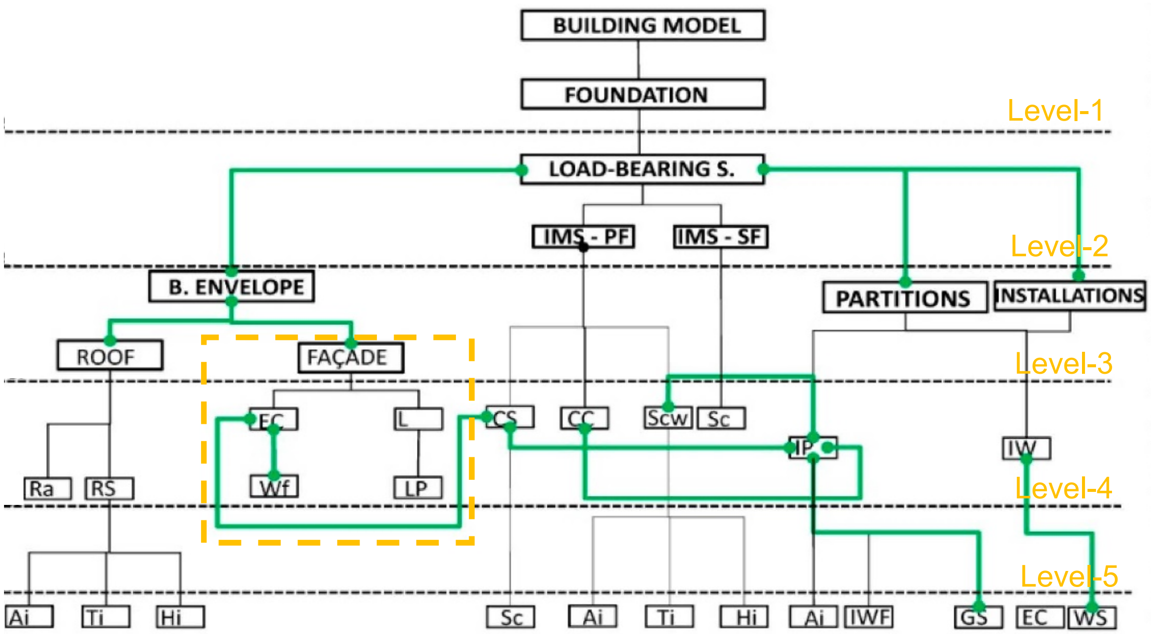
The figure 16: (Rahman, SMM 2018) presents the GM and describes its main parts such as nodes, clusters and edges. a, b, d, e, f, are nodes – elements – components, is equivalent to a column of the load-bearing structure, partition wall and water pipe. A, B, C, D are cluster – assemblies of elements where the elements may be components or subsystems. They are equivalent to load-bearing structure such as concrete skeleton composed of beams, columns and hollow core slabs. Edges are different types of connections. The edges shows the relations between different elements in the structural configuration model. They have the major importance in evaluation of dependency conditions in existing massive structures and are taken into consideration for development of the new retrofitting strategies of the system's configuration.

According to Graphic Model (GM) diagram different types of connection has been established. From there it has been evaluated the dependency conditions between different parts in IBM framing. Simple connections between nodes and clusters allow disassembly in system's configuration. The cluster belongs to higher level in the IBM hierarchy assembly referring the Figure 15: (Rahman, SMM 2018) and node is at the lower level that can change more frequently. Any fixed connection between elements placed in different hierarchical levels is a 'non-desired edge'. Fixed connection between two components from different levels is a 'conflict structural spot' when making changes can end up with a major demolitions and waste disposal. [11]

The systematic approach to analyze existing building gives a clear and scientific idea about the building regarding refurbishment work. It helps to decide the possible extent of intervention in a given condition. This approach will apply on the exemplar building to find out the exact scope of refurbishment of its envelope next.

3.4.2 Building 6 scenario

The GM (Graphic Model) from figure 17: (Rahman, SMM 2018); represents that the major subsystems are independent from main structure. There are demountable mechanical joints in facade panels and load-bearing system. The demountable joining also consists in between partitions and load-bearing system, partitions and installations and in installation and load-bearing system. Those can be refurbished on different levels of its arrangements. The interior partition can be reorganized for functional modification and spatial upgrading.



PF - Slab-Column Skl.
SF – Secondary Str.
CC – Concrete Column
CB – Concrete Beam
CS – Concrete Slab
Ssw – Shear Wall
Sc – Stair Case

SERVICES
WS – Water Supplies, pipes and ducts
GS – Gas Supplies
EC – Electricity Cables
IW – Installation Walls

FACADE
EC – Exterior Cladding
Wf – Windows Frame
A – Air chamber
LP – Loggia Parapet
L – Loggia

ROOF
RS – Roof Slab
Ra – Attic
Ti – Thermal Insulation
Ai – Acoustic Isolation

INFILL
IP – Interior Panel
SCF – Suspended Ceiling
CF – Ceiling Finishing
IWF – Interior Wall Finishing
Aa – Acoustic Isolation

FLEXIBLE EDGE
FIXED EDGE

Figure 17: Graph Model for the building 6 (Rahman, SMM 2018). Adopted from [3]

The shear walls for the horizontal loads are prefabricated components. Position for the shear walls is fixed in the building layout. IMS structural span is 3.43m and 4.00m which has flexible housing layout and facade perimeter line. Facade perimeter line runs outside or outer edge of the edge columns line. All interior partitions are non-load bearing components of metal studs with plaster board cover.

The building lift cores are prefabricated elements. The components were executed from 10 cm thick prefabricated panels. Loggia panels were fabricated in different building technologies as they are directly contacted with the outside weather conditions. Sanitary block is an industrialized block. Managing the installation pipes and ducts through the holes in the cassette floor slab was very common. The IMS floor slab was easy to adapt, providing only a necessary holes for sanitary blocks connection.

The typical facade solution of horizontal seals and windows are placed with industrialized panels. A complete facade panel is composed of a parapet wall, window and vertical member between windows. All openings were pre-fabricated and filled in between RCC panels. The solid facade panels are industrialized components working as the shear walls for horizontal loads. Facade cladding is supported floor to floor by semi-mechanical joints shown in figure 18: (Rahman, SMM 2018). Building 6 facade systems those are windows system, exterior cladding, planter box, loggia with railing and the ventilating system are prefabricated elements and fixed with demountable mechanical or semi-mechanical joins. Therefore, these components are replaceable with minimum interventions.

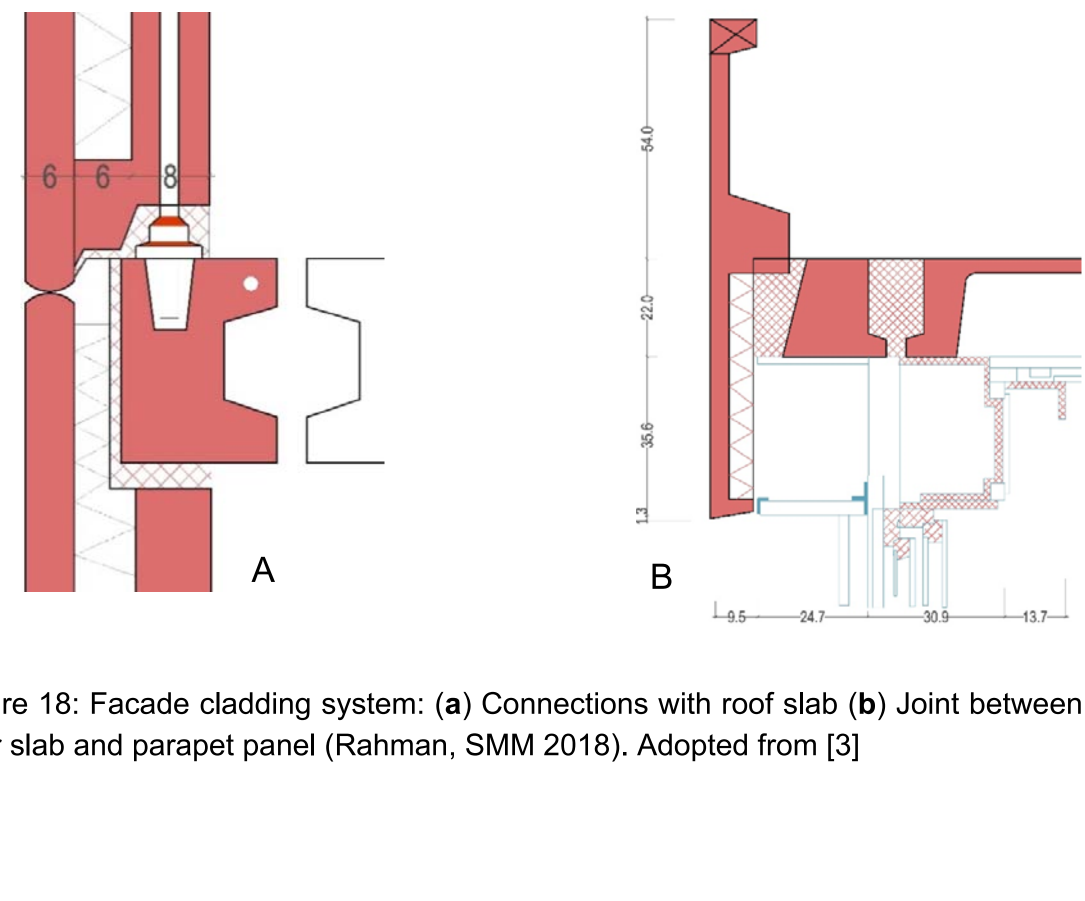


Figure 18: Facade cladding system: (**a**) Connections with roof slab (**b**) Joint between floor slab and parapet panel (Rahman, SMM 2018). Adopted from [3]

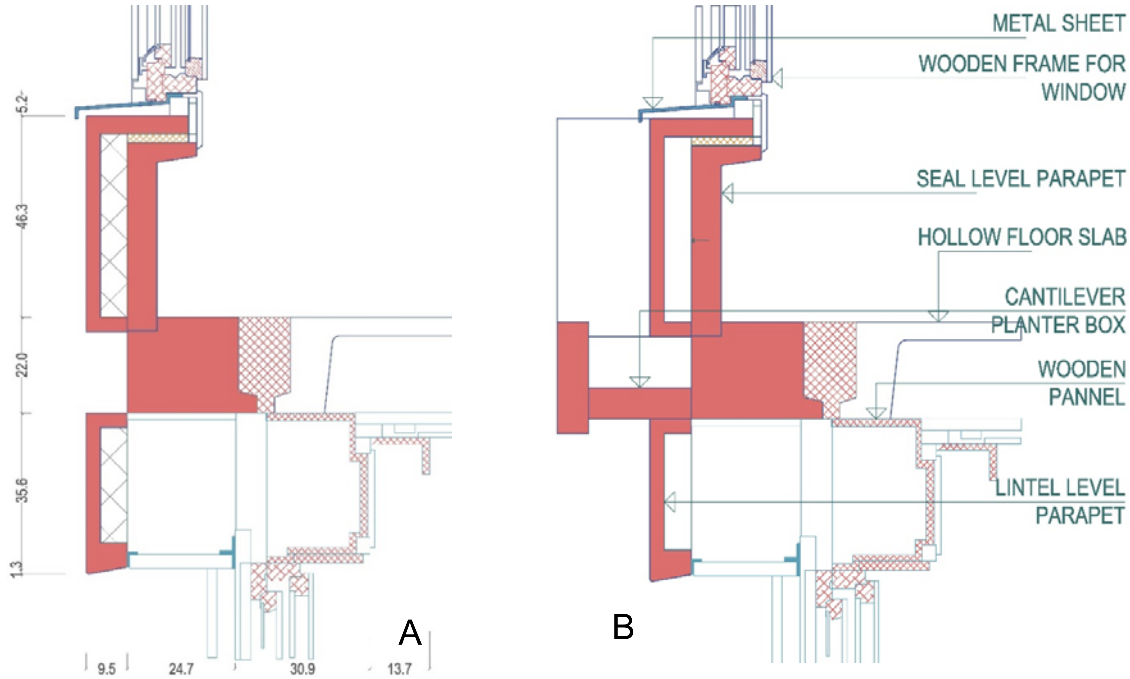


Figure 19: Facade cladding system: (**a**) Joint between floor slab and parapet panel (**b**) Joint between floor slab planter box (Rahman, SMM 2018). Adopted from Anica Dragutinovic, according to the original drawings from Historical Archive Belgrade.

3.5 Simulation as status quo

Before start of simulation, the Building 6 has been built virtually in CAD software named 'SketchUp' according to the original plans, sections and available detail drawings. It has been justified with the original photograph taken by Jadranka Ahlgren (2016). The purpose of this 3D model is to study its facade and structural elements as in original drawings. Figure 20: (Rahman, SMM 2018) are two three dimensional impression of the Building 6. By this 3D model study the perception of space became clearer. Thus it helps to generate more accurate Simulation model for daylight analysis.

Figure 20 A, B: Computer generated Architectural impression of Building 6 (Rahman, SMM 2018)

3.5.1 Energy simulation

For the simulation of energy and for the daylight simulation it has been considered the floor area showing in figure 21: (Rahman, SMM) of the level 3 of existing building according to the original drawings. Energy analysis program embedded with Revit has been used to simulate this data.

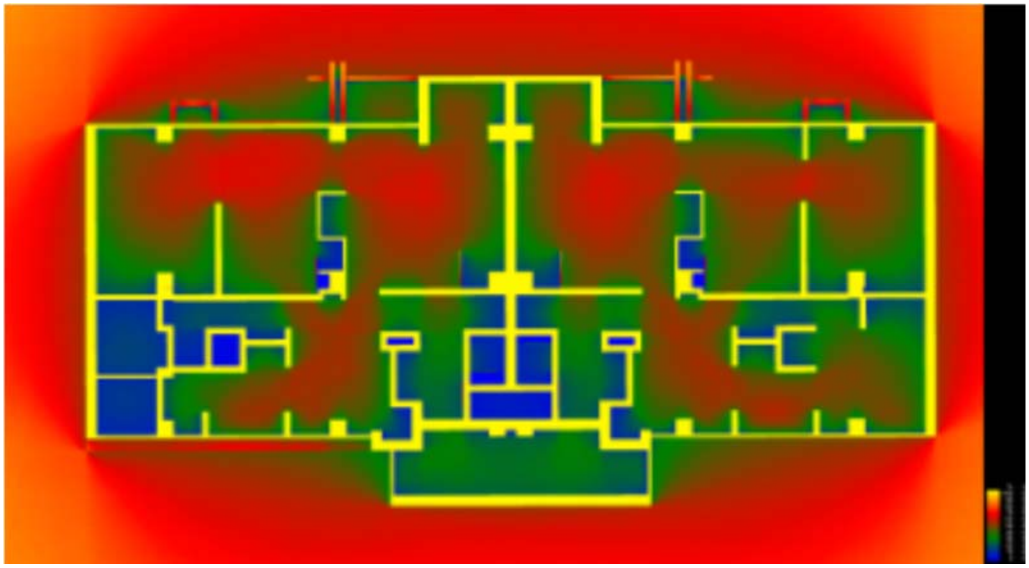


Figure 21: Energy distribution (Rahman, SMM 2018).

Location:	Belgrade, Yugoslavia
Weather Station:	171981
Outdoor Temperature:	Max: 94°F/Min: 6°F

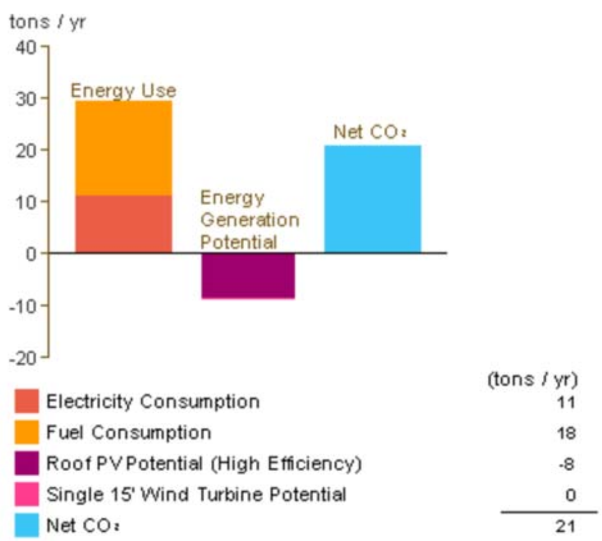


Figure 22: Annual Carbon Emission (Rahman, SMM 2018).

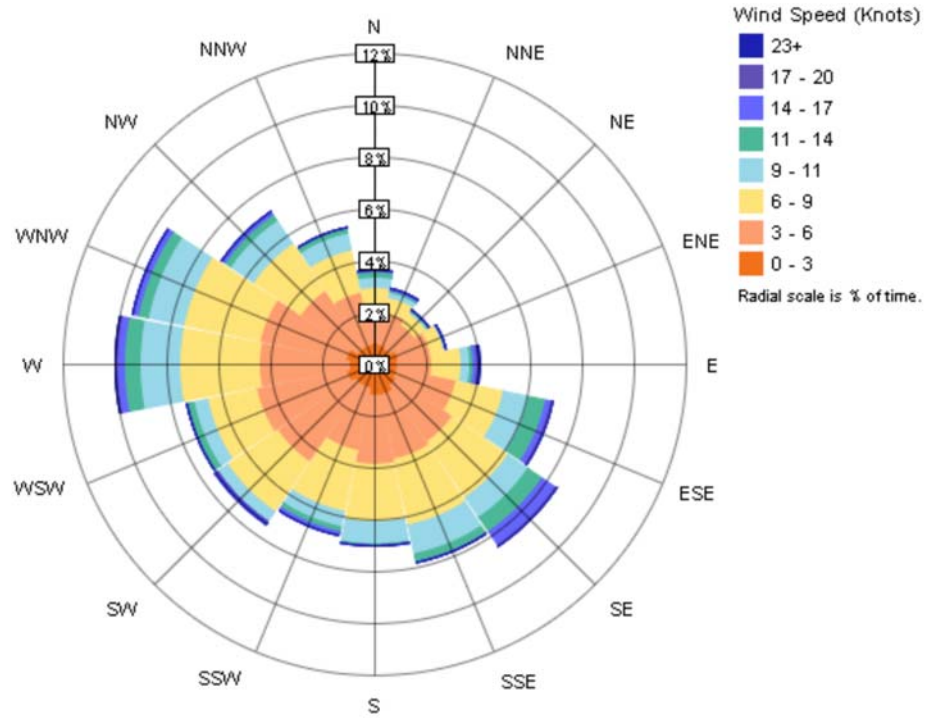


Figure 23: Annual Wind Rose - Speed Distribution (Rahman, SMM 2018).

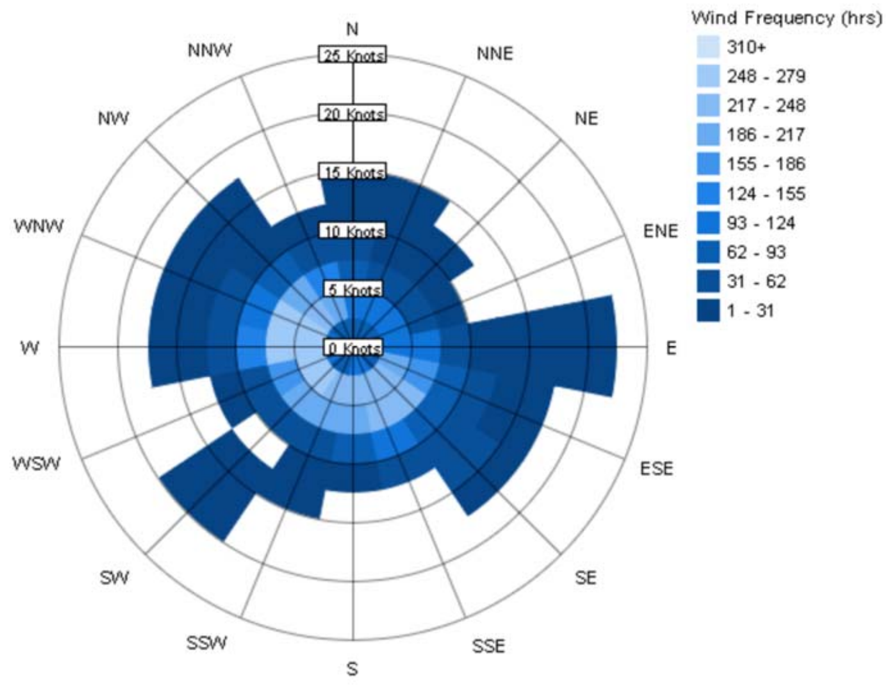


Figure 24: Annual Wind Rose - Frequency Distribution (Rahman, SMM 2018)

The frequency of prevailing wind in a year is indicated in the figure 23 (Rahman, SMM 2018). The wind is dominated by west-north-west and east to east-south-east direction. The speed of wind is mostly within 25 km/h and the average velocity is 10 km/h. Since New Belgrade is cold in winter, the prevailing wind is analyzed in winter. According to figure 25 (Rahman, SMM) the prevailing wind in winter comes from south side, bringing cold air with high humidity. This directs the design to take necessary precautions in winter. On the other hand in summer, the direction of the prevailing wind is from the west and north-west side while the average temperature is above 25°C. The microclimate condition is crucial to consider in design phase.

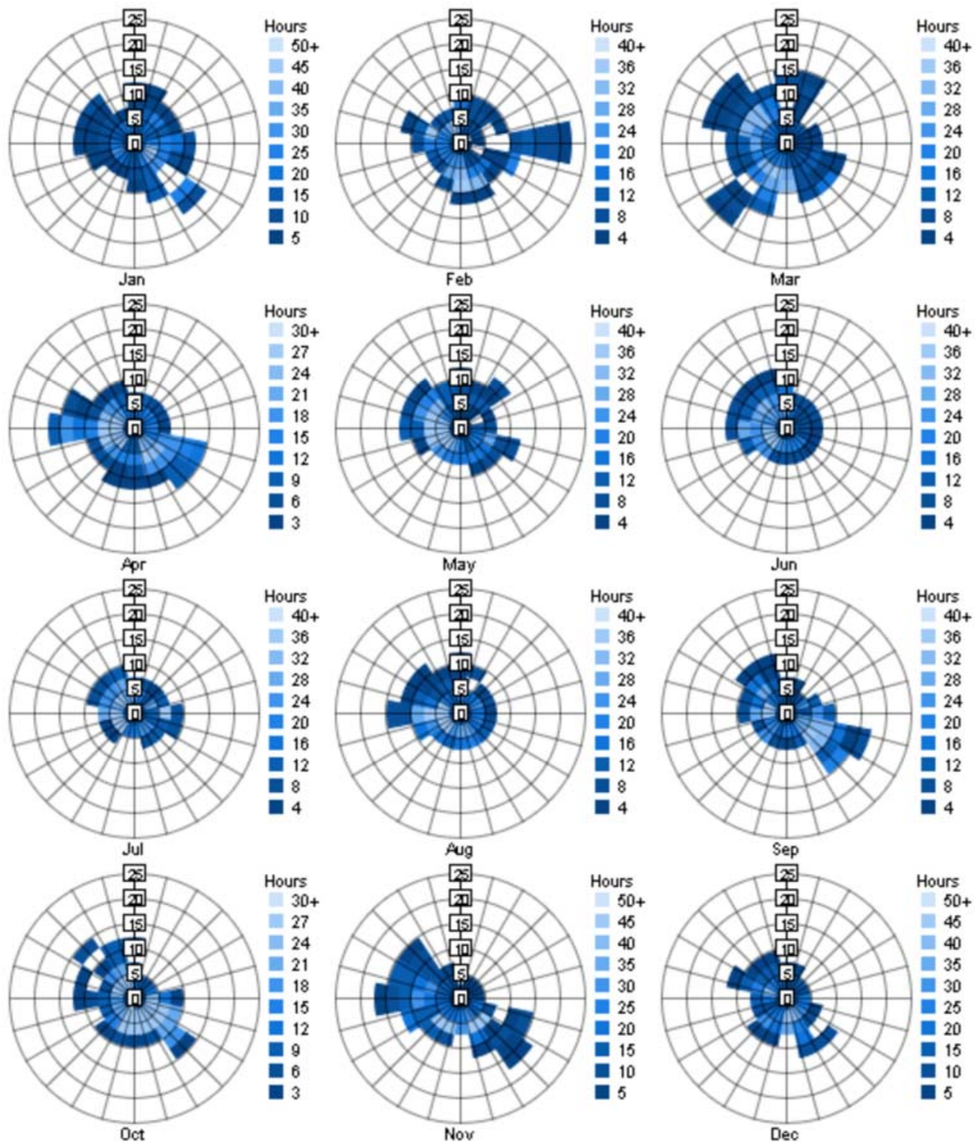


Figure 25: Monthly Wind Rose (Rahman, SMM 2018)

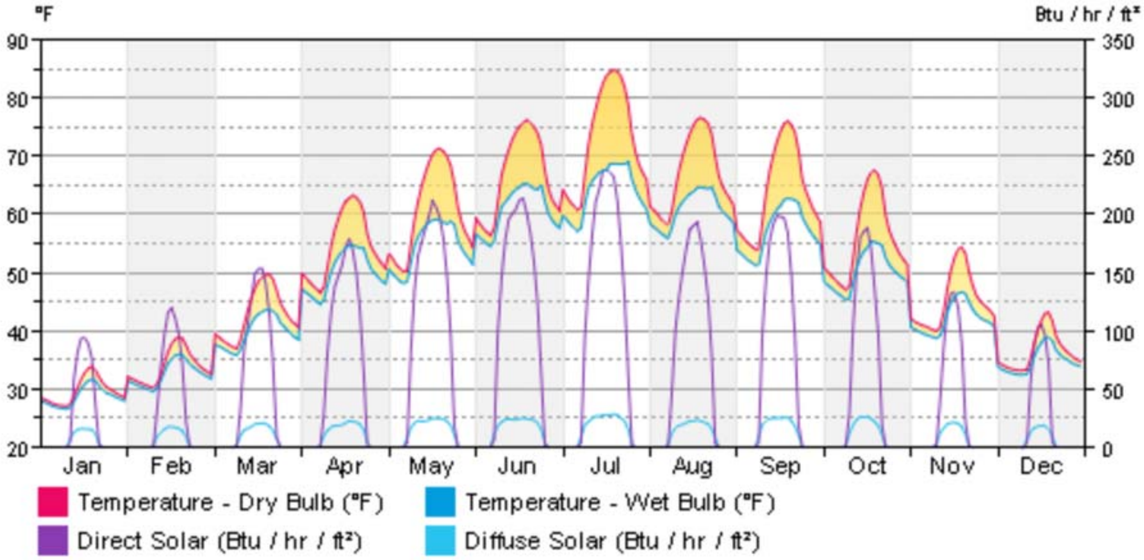


Figure 26: Diurnal Weather Averages – Temperature (Rahman, SMM 2018)

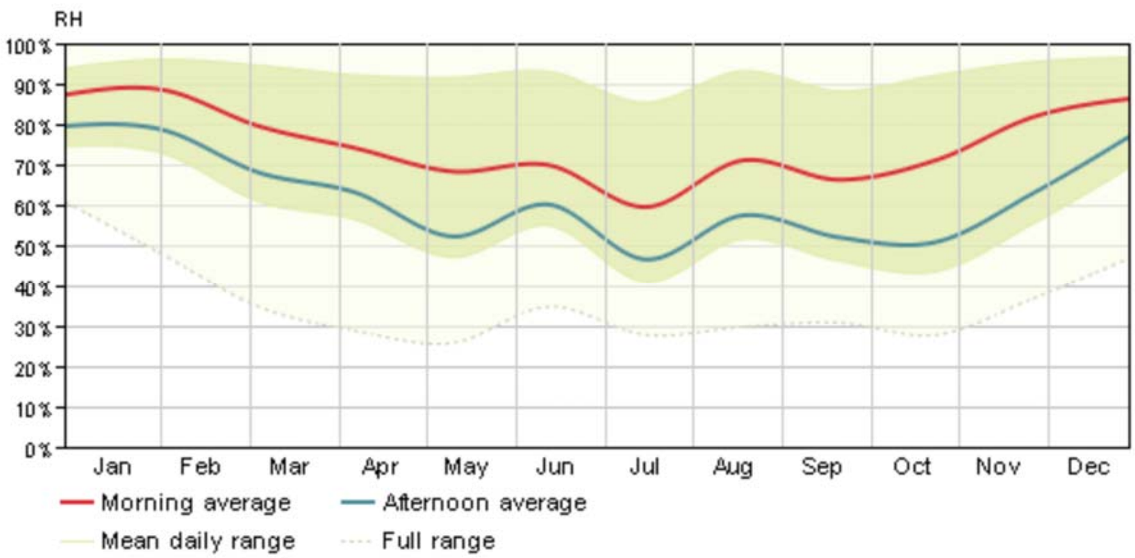


Figure 27: Diurnal Weather Averages – Humidity (Rahman, SMM 2018)

New Belgrade is in the humid subtropical climate zone. The monthly average temperature ranges from 1.4°C (34.5°F) to 23°C (73.4°F) respectively in January and July. It receives 690 millimeters precipitation in average annually. The figure 26: (Rahman, SMM 2018) above indicates that, in New Belgrade, the temperature difference is almost 50°C (122°F) in average year. In the winter season from November to January, the humidity reaches its peak to 89% Figure 27: (Rahman, SMM 2018).On the other hand, in summer the situation is quite comfortable in terms of humidity.

3.5.2 Daylight simulation

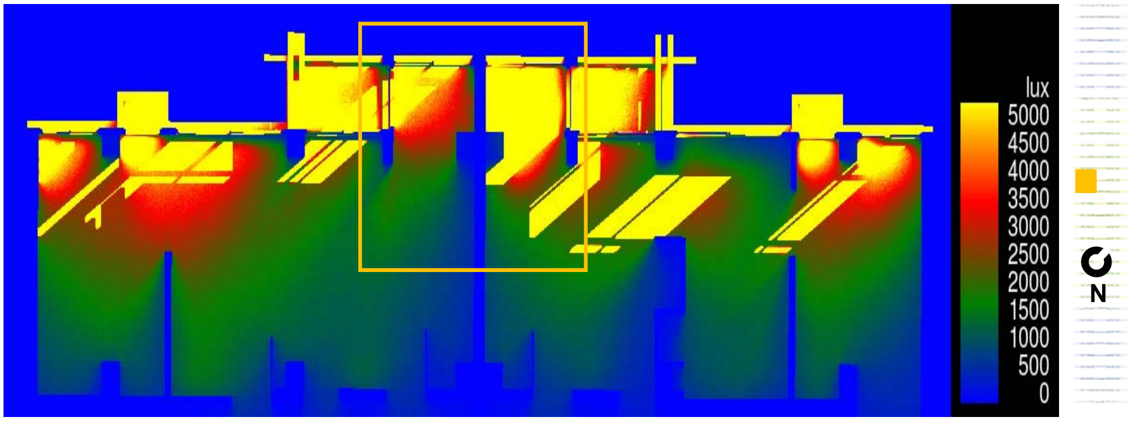


Figure 28: Daylight simulation in Revit (Rahman, SMM 2018)

In the figure 28: (Rahman, SMM 2018), the daylight situation has been simulated in 'Revit 2016' software. The location has been considered the city of Belgrade where the latitude = 44.8° and longitude = 20.4667° has been considered to pin point the site location. North direction is 38° anti clock along the longitudinal axis of the building. Thus the experimented room orientation is toward south-west. The altitude is considered 9.14m which is the second floor table height. To simulate this space 16:00 hrs of 25th June, 2018 has been considered. The sky setting is 'ICE clear sky' having DNI=752 w/m^2, DHI=92 w/m^2.

According to Velux, the illuminance unit lux is the measure of the amount of light received on a surface. It is the measure of light currently used by most performance indicators to determine daylight availability in the interior. The reference value for a residential space is 200-500 lux. The considered room is found the illuminance over 1500 lux. Therefore, a Shading device is required to protect over light and glare.

3.6 Conclusion

The analysis on basis of refurbishment potential showed that the building is very much fit for systematic refurbishment. The secondary structures such as partition walls, balconies, shading parapets are easily removable. The windows are also prefabricated and constructed as 'in-fill' process and those are also easily removable. The primary structure has sufficient stability to hold new refurbishment components such as insulation cladding and glazing in the facade, shifting of partition walls, fitting and fixtures of plumbing systems as well as electrical wiring. Modern communication and safety instruments can be added with the existing primary structure. The following chapter will investigate the climate of New Belgrade. Some variants of shading integrated facade system will be described and compared. Finally selected variants will later apply for the refurbishment of New Belgrade 'Mass-housing' envelope.

4. Shading Integrated Adjustable Facade; *Compatibility on exemplar building*

4.1 Introduction

A Shading Integrated Adjustable Facade which may be called as SIAF is a system where the outer skin consists of two parts. The lower portion is clear glass up to over human eye level and the upper portion is usually opaque up to overhead ceiling. This portion will act as shading which is usually opaque but the material may be translucent or even transparent. The SIAF is able to move outward and inward respecting the sun angle. User can adjust the facade according to their need of sun though they will not lose their view noticeably.

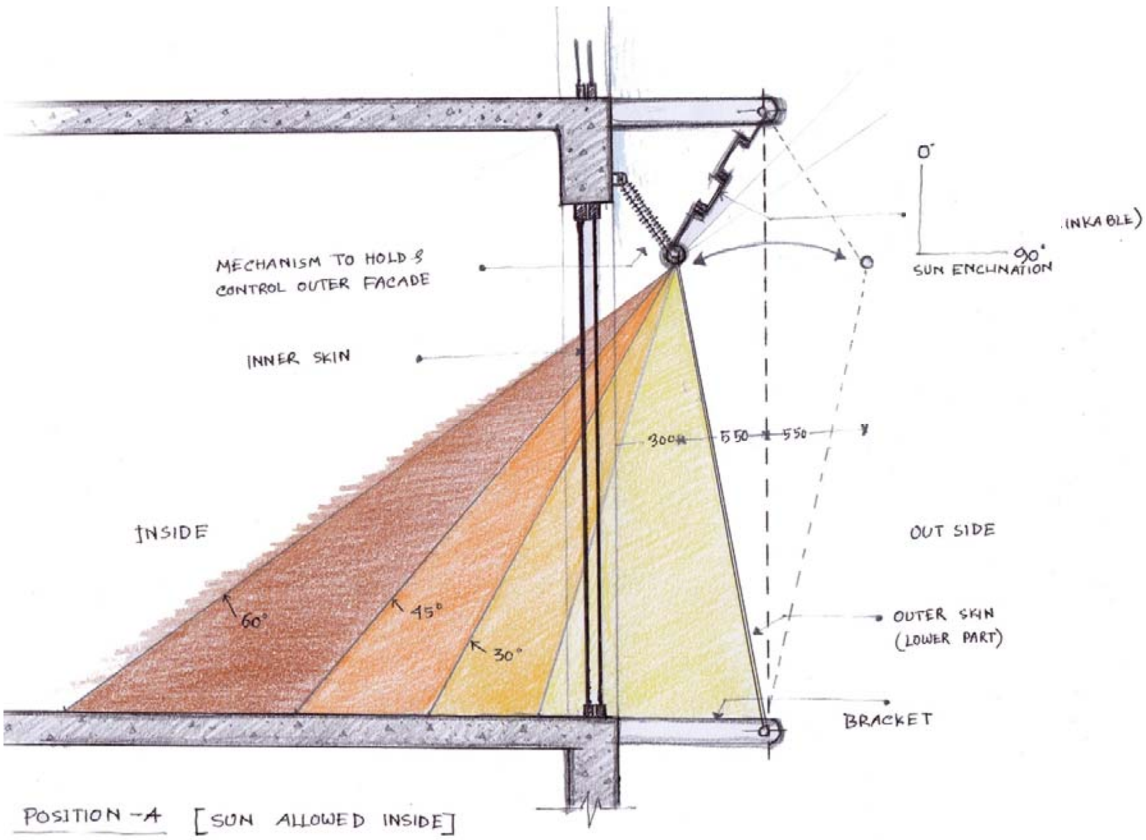


Figure 29: SIAF as Double Skin Facade; position-A when sun is allowed inside (Rahman, SMM 2018).

However, Csoke (2011) wrote about adaptive facade in her Master Dissertation book. Where she proposed a facade system whose shading is integrated with the facade and can be adjusted only outward from vertical position referring figure: 30 (Csoke, C 2011). [14] This system has the closest relation with SIAF.

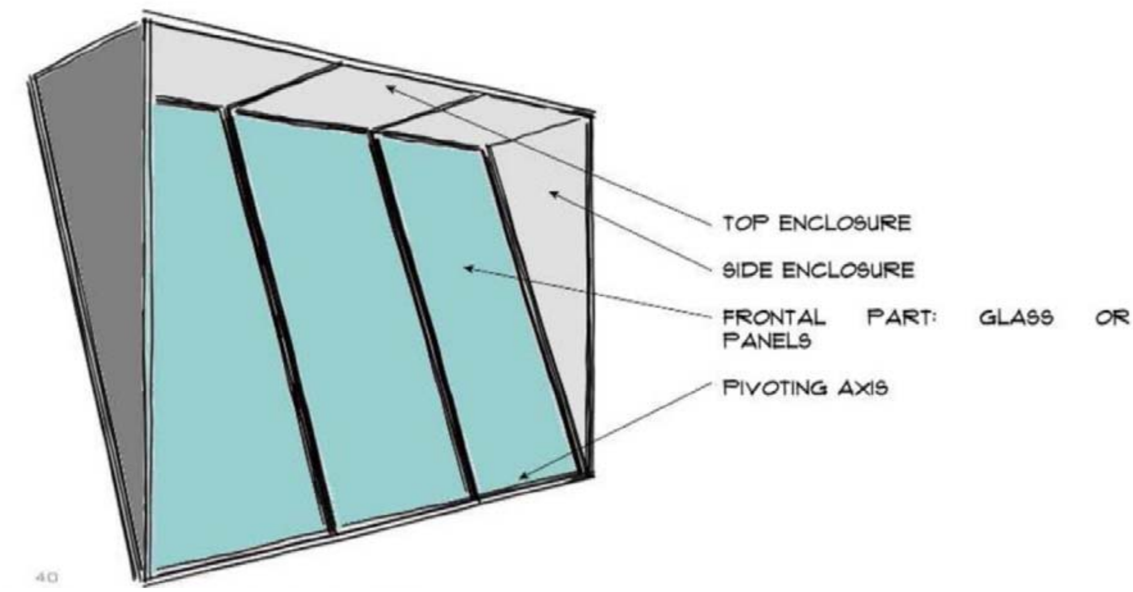


Figure30: The Add-on system of Adaptive Facade, (Csoke, C 2011).

SIAF can be used as double skin facade or as single skin facade. In the case of double skin facade it will fit as corridor type. That means, there will be a corridor in between inner and outer facade. Really a corridor is not needed indeed. Rather a buffer of around 1.2 meter in between two skin is functionally needed. This space will allow the outer facade to move inward and outward. However, SIAF can be used as single skin facade also. In this case the adjustability of the facade may be limited inward. The applicability of SIAF as double skin or single depends on as usual of applicability of double skin facade or single skin facade. Where there climate is extreme, a double skin may be applicable. On the other hand, situation in mild climate may justify with a solution of single skin facade.

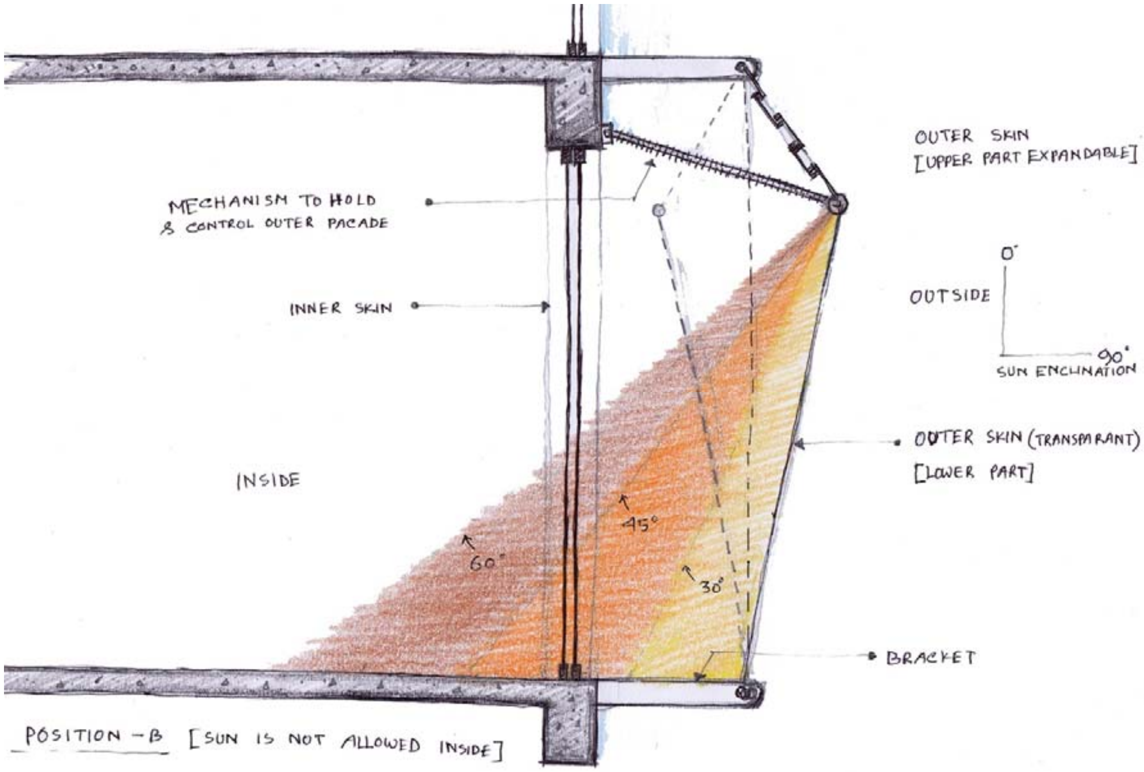


Figure 31: SIAF as Double Skin Facade; position-B when sun is not allowed inside (Rahman, SMM 2018).

In the case of double skin facade SIAF will be plugged-in on primary structure with brackets. The inner facade will be as usual as normal window. A sliding window or pivoted window swing inside or folded window folding inside is suitable to fit with SIAF.

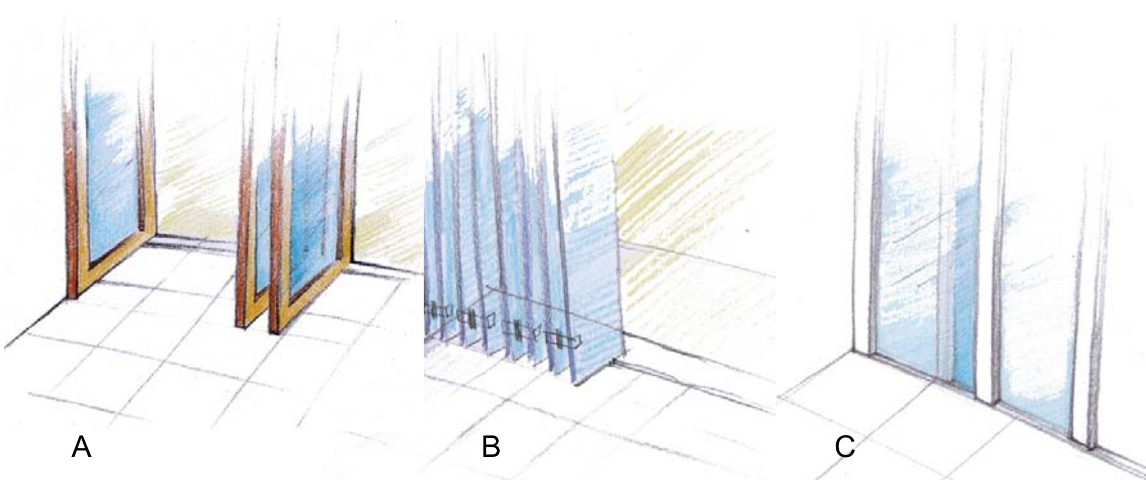


Figure 32: Inner skin option: (A) pivoted (B) Folded (C) sliding (Rahman, SMM 2018).

However, if SIAF is used as single skin facade, it may be fit as 'in-fill' system; the total void area is filled with pre-fabricated SIAF. Another option is, it can be plugged-in on primary structure with bracket. In this case, the gap between the skin and the primary structure is less than the same of double skin facade option. A clearance is required to move the skin inward and to place the mechanism.

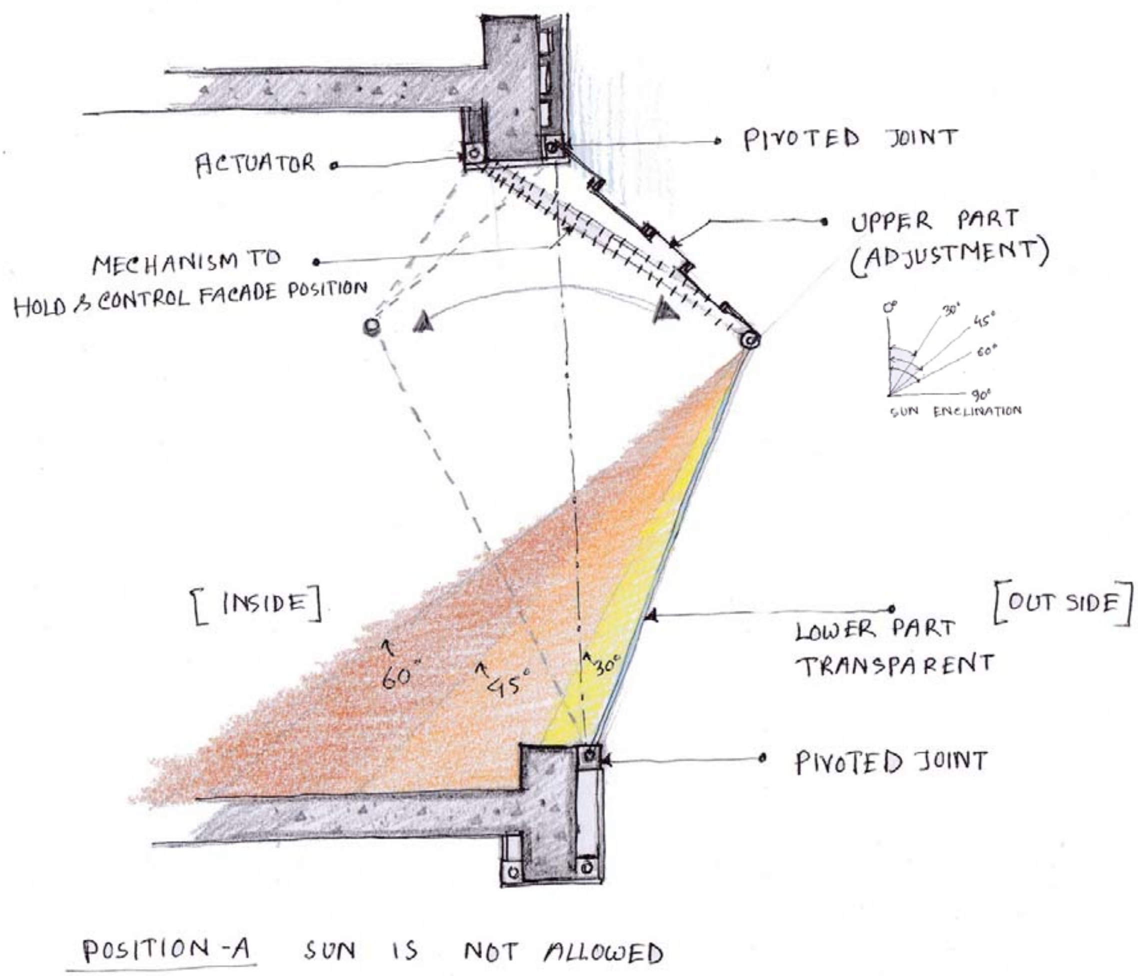


Figure 33: SIAF as Single Skin Facade; Position-A when sun is not allowed inside (Rahman, SMM 2018).

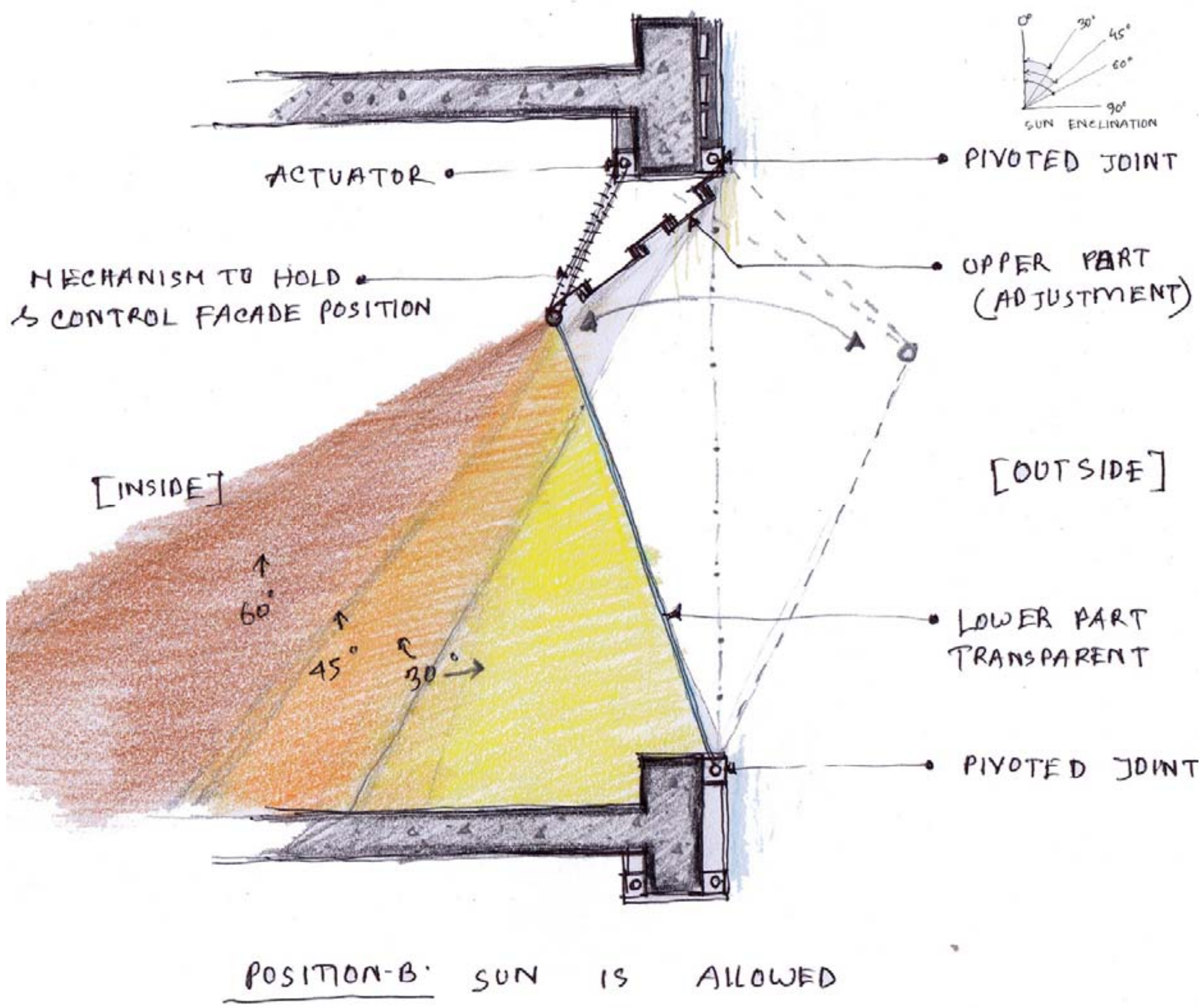


Figure 34: SIAF as Single Skin Facade; Position-B when sun is allowed inside (Rahman, SMM 2018).

4.2 Schematic design of SIAF

The SIAF is movable and it moves centering the bottom pivoted joint with a radius equal to the length of lower part showing in Figure 35: (Rahman, SMM 2018) Position-A and Position-B has different length in upper part. Therefore, a change of length is a must in upper part which is acting as shading device. The figure also shows that, the length of upper part is minimum in Position-A where the facade is vertical and the length is maximum in the Position-B where the inclination of facade is maximum. All the positions other than Position-A cause the extended length of the upper part. The change of length can be expressed as ΔL. If the length of Position-A=L_A and the length of Position-B=L_B then **$\Delta L = L_B - L_A$**. This ΔL will characterize the variation of SIAF mechanically.

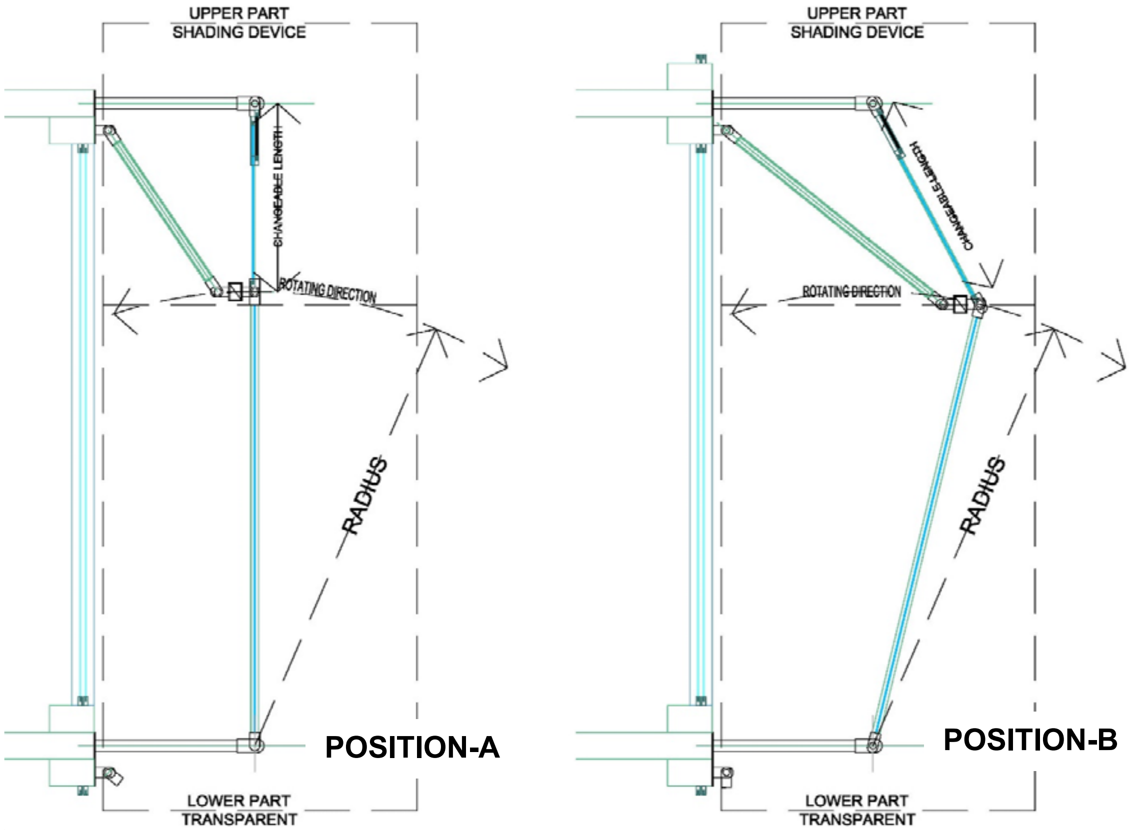


Figure 35: Position-A and Position-B has different length in upper part (Rahman, SMM 2018).

ΔL can be achieved in various ways. It can be achieved by rolling out or by a folded plate or by changing of radius of a curve material or by sliding. An elastic material can also achieve ΔL. Some variation is going to describe in the following headings.

4.2.1 SIAF as double skin

The Figure 36: (Rahman, SMM 2018) Alternative-01, SIAF as double skin shows that the upper part which will act as shading device has two parts. They will slide each other to adjust the length while the facade is moving. A belt or chain will hold the shaft and connected with actuator in one end and the other end will connect with primary structure. Basically this belt is the connection between the outer facade and the main structure. The belt will have the capability to keep the facade ridged in any position within the limit of its movement. The moving mechanism is not limited in belt system. It can be achieved by hydraulic shaft or by threaded shaft connected with gear and so on. Here the variations are limited concerning to ΔL.

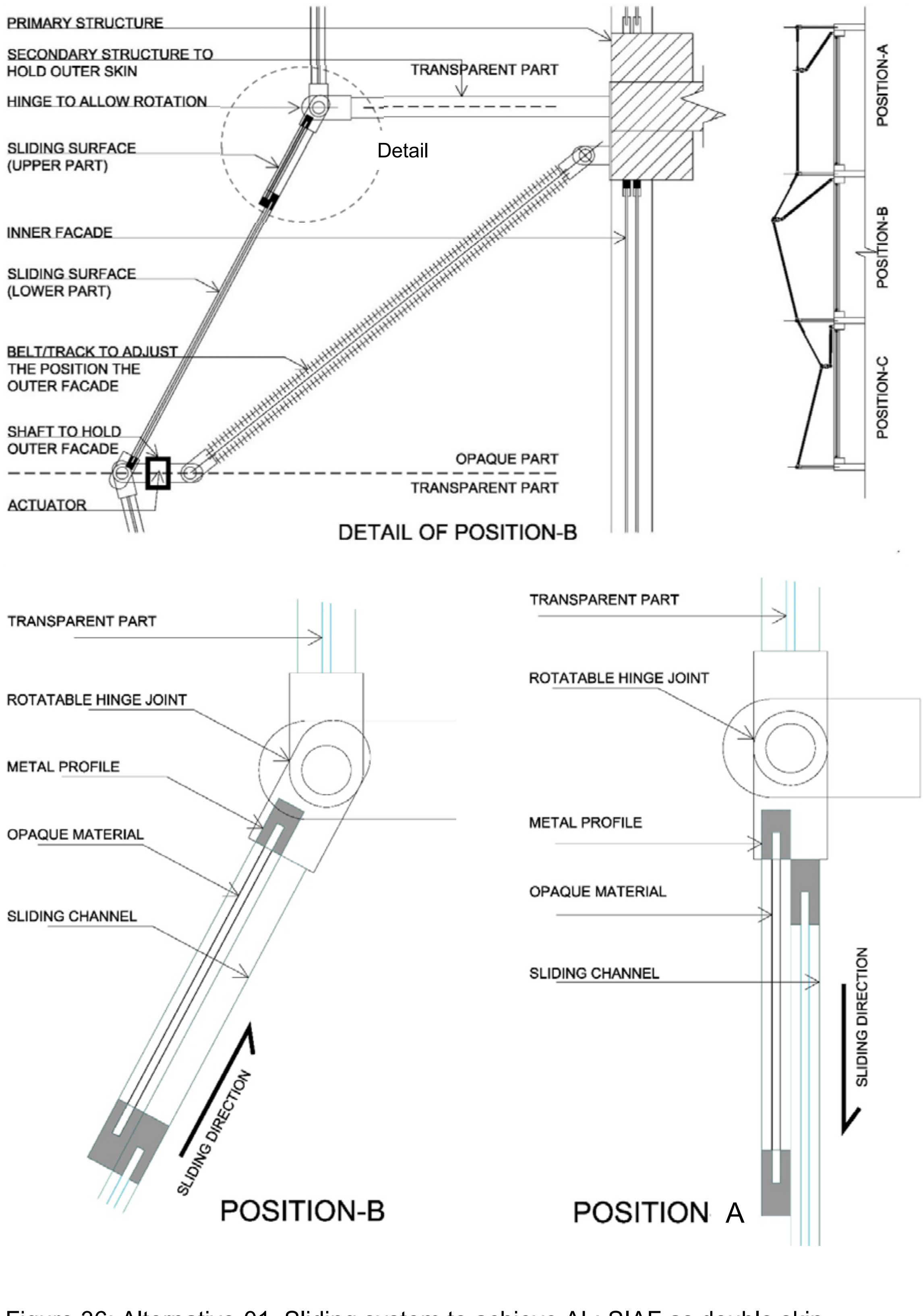


Figure 36: Alternative-01, Sliding system to achieve ΔL; SIAF as double skin (Rahman, SMM 2018).

Figure 37: Alternative-01, Sliding system to achieve ΔL; SIAF as double skin (Rahman, SMM 2018).

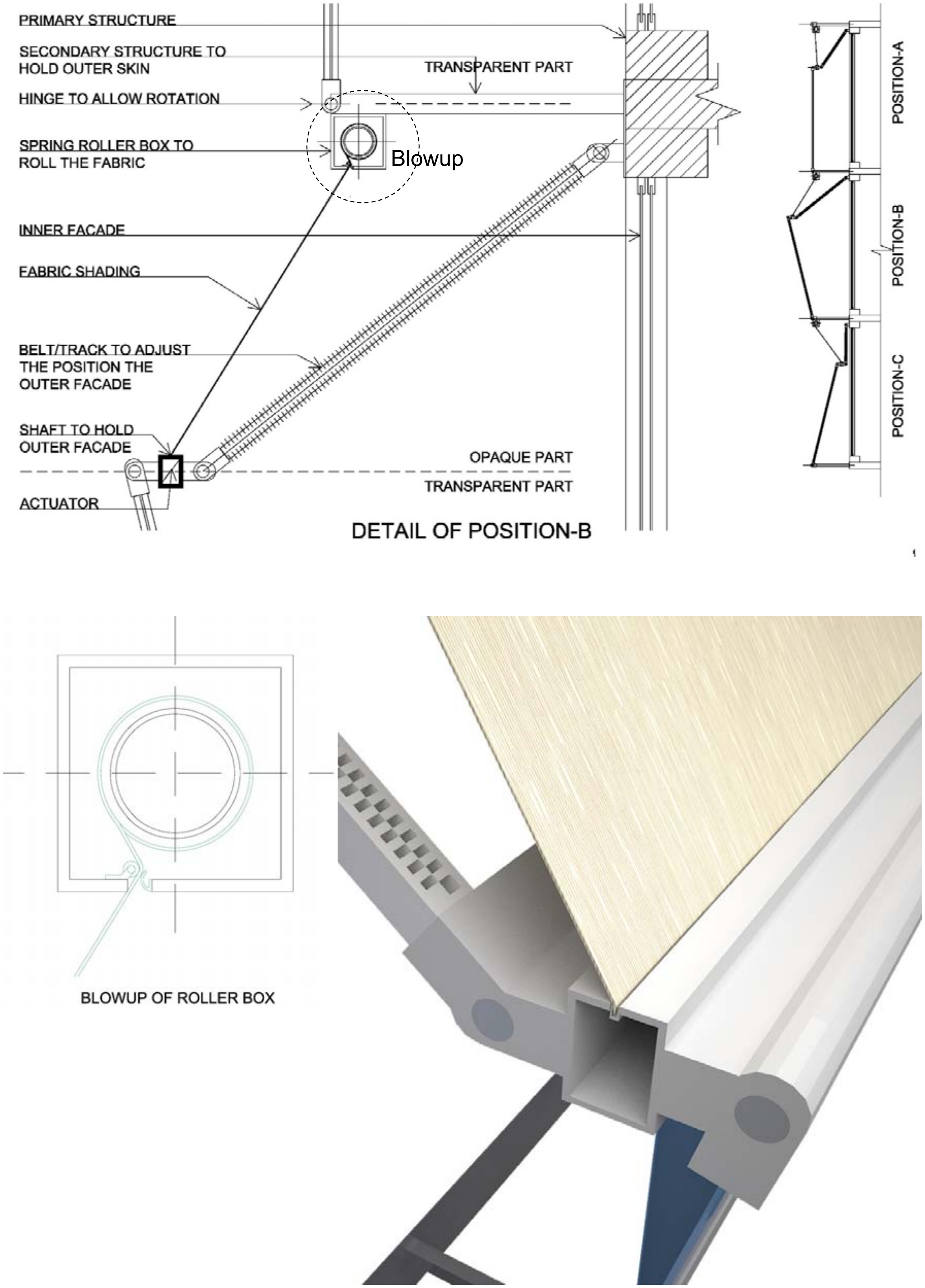


Figure 38: Alternative-02, Roller box system to achieve ΔL; SIAF as double skin (Rahman, SMM 2018).

Alternative two is characterized with a spring roller box in which the upper part is made up of fabric. This fabric is rolled into the box. While the length is needed to be changed the fabric will be rolled out from the box or rolled in into the box referring in the Figure 38: (Rahman, SMM 2018). In this alternative the box is fixed on top of the upper part and it will be visible from outside. There may be wrinkle on fabric while it is moving. Therefore, special attention is needed to solve this issue. The holding mechanism is considered as same as alternative one.

Alternative three is less complicated to achieve ΔL. The upper part of this system is made up with folded metal plate. The metal plate will be elastic enough to adjust the length required to move the facade. The upper open end in cross section is clipped with a metal profile that is fixed with main bracket and the lower end will be clipped with the main shaft (transom). This transom is movable by the belt showing in the Figure 39: (Rahman, SMM 2018).

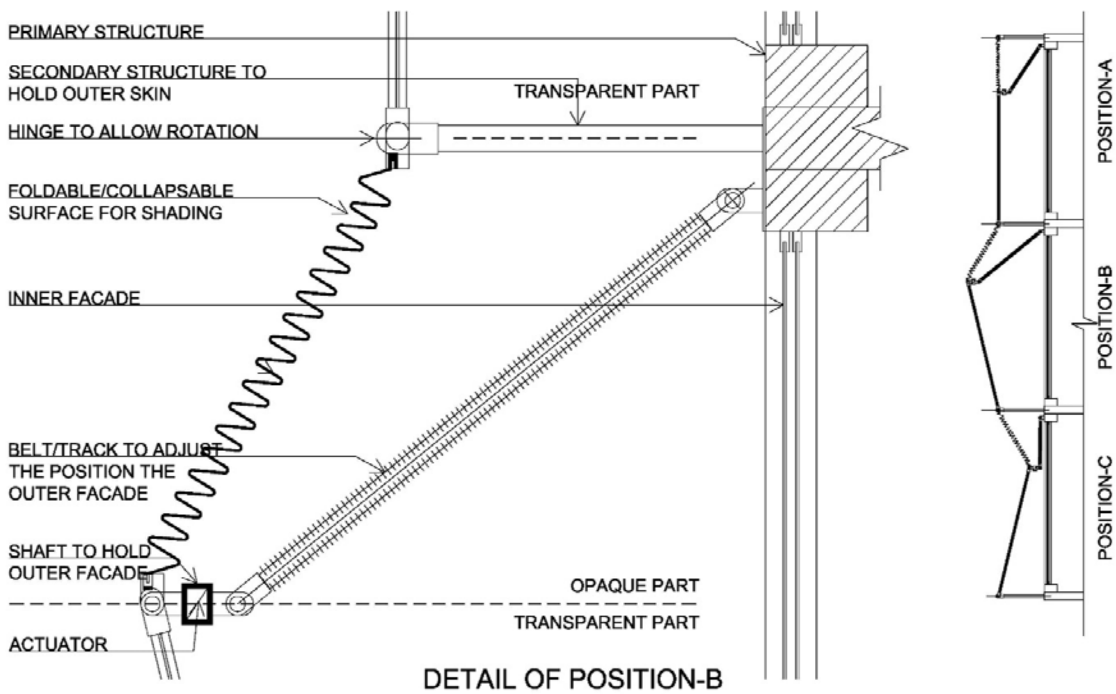


Figure 39: Alternative-03, Folded plate system to achieve ΔL; SIAF as double skin (Rahman, SMM 2018).

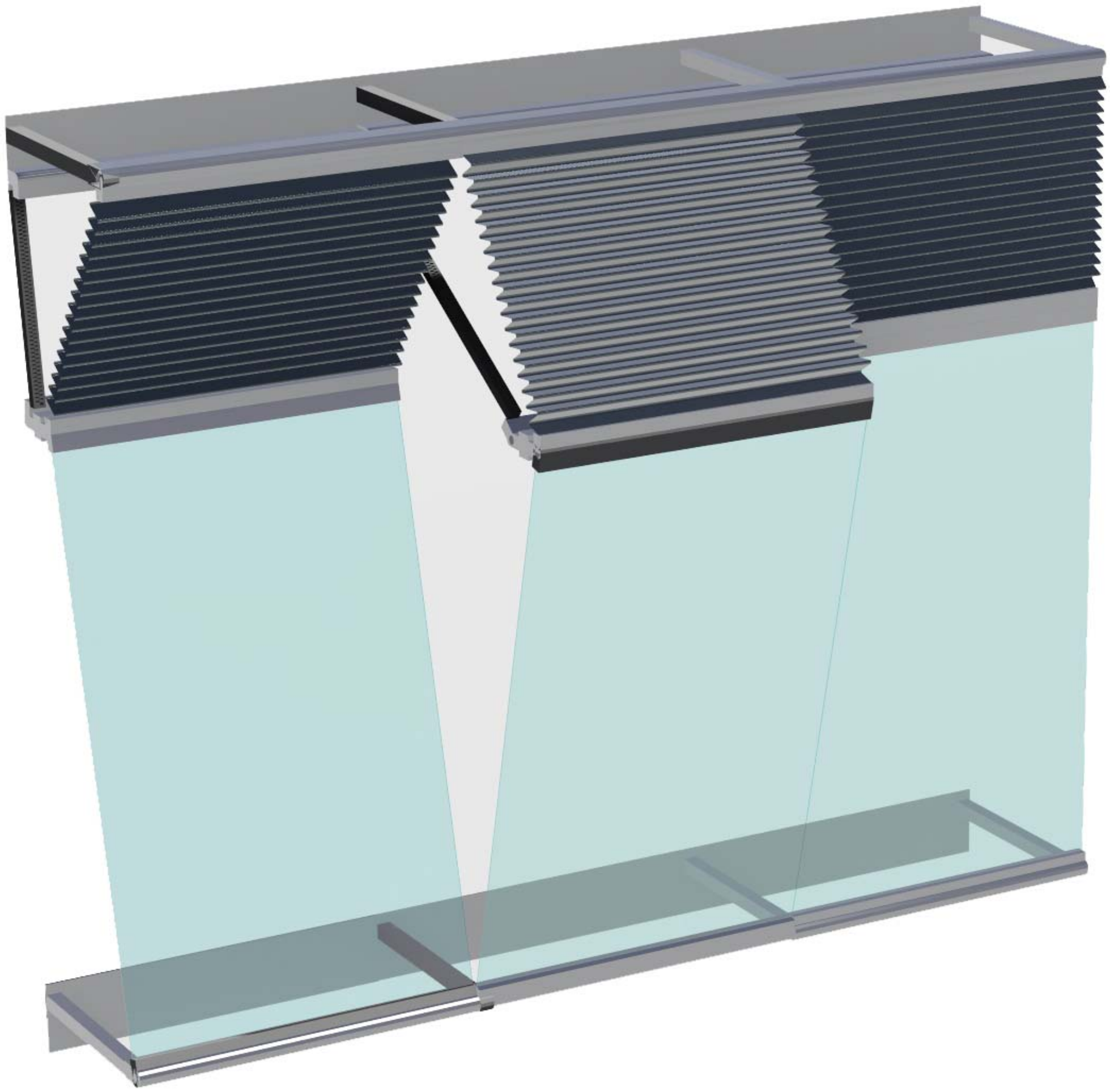


Figure 40: Alternative-03, Folded plate system 3D Appearance (Rahman, SMM 2018).

Alternative four is also a simple solution. In this system the upper part of the system is made up of an arc shape metal sheet in cross section referring the Figure 40: (Rahman, SMM 2018). This arc is capable to change its radius to achieve ΔL. As the material will change its radius frequently, the flexibility of the material is needed to be ensured.

As a matter of fact the variation on basis of ΔL may be achieved in other ways also and each option can be achieved by various materials of required properties. The color of the material also can be diversified with users demand. The mechanism to move the facade can be achieved in several ways. Thus the Shading Integrated Adjustable Facade (SIAF) will open new era of customization and variation both by the consumer and by the producer. However, the user will get vast alternatives to personalize their own space while harmony of the facade will not futile.

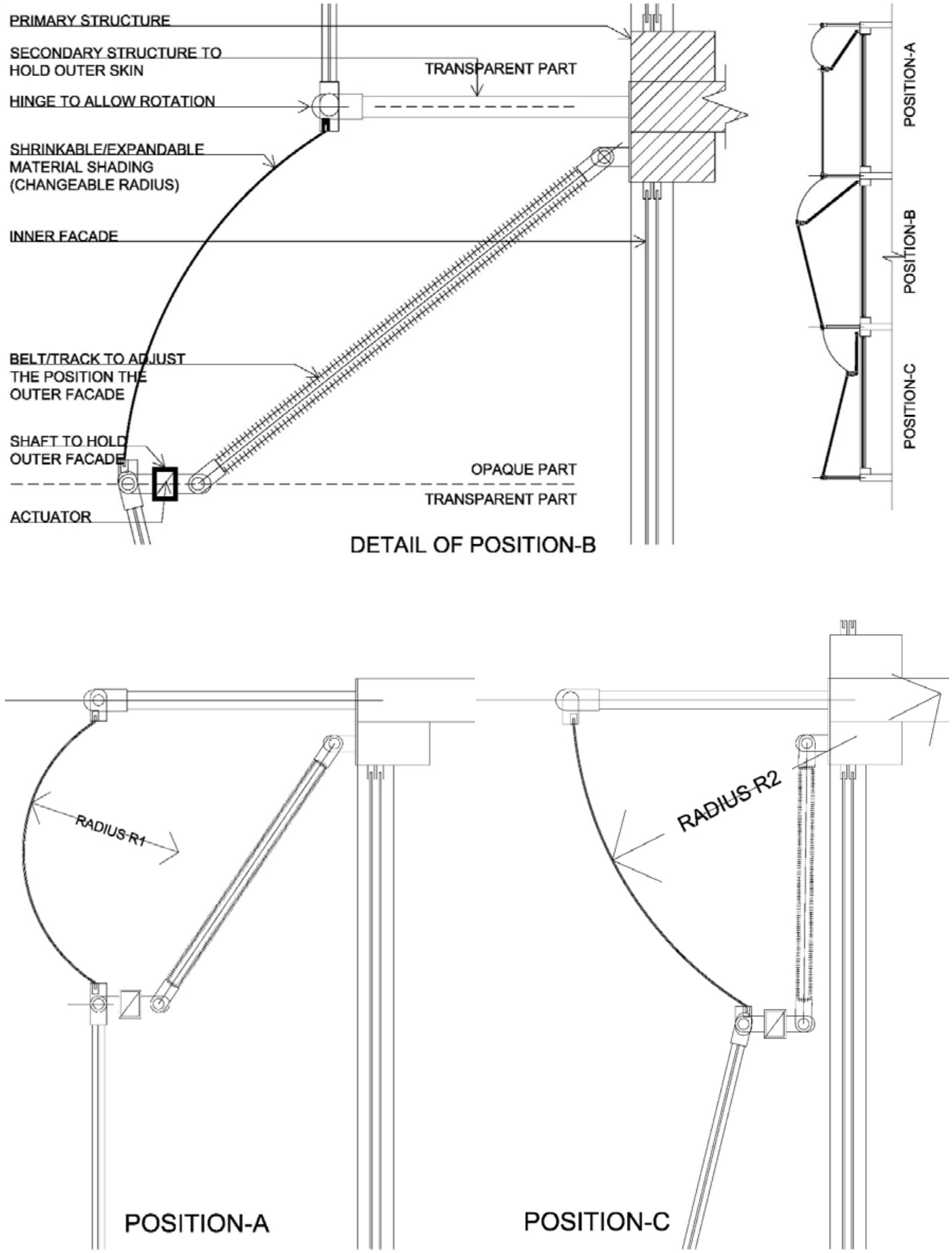


Figure 41: Alternative-04, Arc plate system to achieve ΔL; SIAF as double skin (Rahman, SMM 2018).

Figure 42: Alternative-04, Arc plate system to achieve ΔL; SIAF as double skin (Rahman, SMM 2018).

4.2.2 SIAF as Single skin

SIAF as single skin is same as double skin but the structural mechanism to set on primary structure is different. The operational mechanism may differ from the double skin system as there is less or no additional space to set those. Due to differing the structural mechanism the architectural appearance may differ from the double skin. However, the scheme to achieve the ΔL is same. As the exemplar building is going to describe with SIAF as single skin in next chapter, the elaboration of this system has been omitted to avoid repetition.

4.3 Compatibility of SIAF on exemplar building

In the previous chapter it has been shown that the building 6 in block-23 of New Belgrade is structurally capable to fit with new facade system as part of refurbishment. However, which type of the SIAF is fit for the exemplar building is vastly depending on climate of the site though economy also a factor.

4.3.1 Climate of the site

New Belgrade is a part of the city of Belgrade which is situated in the humid sub-tropical zone of south-eastern Europe. It has four season and almost uniform precipitation. Monthly averages range of temperature is from 1.4 °C in January to 23.0 °C in July whereas the annual mean temperature is 12.5 degree Celsius. There are, on an average 95 days when the temperature is above 25 °C. The city of Belgrade receives about 691 millimeters of precipitation a year in which the late spring, May and June being the wettest. The average annual number of sunny time is 2,112 hours. The highest insolation of about 10 hours a day is in July and August, while December and January are the cloudiest, with insolation of 2 to 2.3 hours per day. The average number of snowy days is 27 where snow cover lasts from 30 to 44 days with average thickness of 14 to 25 centimeter. The mean atmospheric pressure in Belgrade is 1,001 milli-bars and mean relative humidity is 69.5%. The climate of Belgrade is also characterize by 'Košava' - the southeast-east wind. It brings clear and dry weather which blows mainly in autumn and winter in an intervals of two to three days. The average speed of 'Košava' is 25-43 km/h but certain strokes can reach up to 130 km/h. 'Košava' is the largest air cleaner of Belgrade. [4], [5]

The climatic data of Belgrade shows that April to October has average temperature ranging between 12.9 and 28.7 degree Celsius and relative humidity 61% and 71%. Therefore, a very good cross ventilation is needed in interior environment. Thus, the facade system should have sufficient opening possibility. In these months sun also shines brighter which is ranging from163.1 to 290.8 hours per month. Therefore, a sun shading system is also required. In summer season, the direction of the prevailing wind is from the west and south-west side. Moreover, the average temperature, being above 25°C. Since the microclimate condition is crucial in design phase detail wind analysis is required for design decision.

On the other hand, from November to April, it is observed that, the average temperature is in between 2.7°C and 7.6°C with a range of average low from -1.1°C to 4.2°C. Therefore, heating system is needed in interior environment. Moreover, a very good insulation is required to protect heat loss. It will be an extra advantage to allow solar heat inside the room. Since Belgrade is cold in winter, the prevailing wind in winter

Climate data for Belgrade (1981–2010)													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	20.7 (69.3)	23.9 (75)	28.8 (83.8)	32.2 (90)	34.9 (94.8)	37.4 (99.3)	43.6 (110.5)	40.0 (104)	37.5 (99.5)	30.7 (87.3)	28.4 (83.1)	22.6 (72.7)	43.6 (110.5)
Average high °C (°F)	4.6 (40.3)	7.0 (44.6)	12.4 (54.3)	18.0 (64.4)	23.5 (74.3)	26.2 (79.2)	28.6 (83.5)	28.7 (83.7)	23.9 (75)	18.4 (65.1)	11.2 (52.2)	5.8 (42.4)	17.4 (63.3)
Daily mean °C (°F)	1.4 (34.5)	3.1 (37.6)	7.6 (45.7)	12.9 (55.2)	18.1 (64.6)	21.0 (69.8)	23.0 (73.4)	22.7 (72.9)	18.0 (64.4)	12.9 (55.2)	7.1 (44.8)	2.7 (36.9)	12.5 (54.5)
Average low °C (°F)	−1.1 (30)	−0.1 (31.8)	3.7 (38.7)	8.3 (46.9)	13.0 (55.4)	15.8 (60.4)	17.5 (63.5)	17.6 (63.7)	13.5 (56.3)	9.0 (48.2)	4.2 (39.6)	0.2 (32.4)	8.5 (47.3)
Record low °C (°F)	−26.2 (−15.2)	−15.4 (4.3)	−12.4 (9.7)	−3.4 (25.9)	2.5 (36.5)	6.5 (43.7)	9.4 (48.9)	6.7 (44.1)	4.7 (40.5)	−4.5 (23.9)	−7.8 (18)	−13.4 (7.9)	−26.2 (−15.2)
Average precipitation mm (inches)	46.9 (1.846)	40.0 (1.575)	49.3 (1.941)	56.1 (2.209)	58.0 (2.283)	101.2 (3.984)	63.0 (2.48)	58.3 (2.295)	55.3 (2.177)	50.2 (1.976)	55.1 (2.169)	57.4 (2.26)	690.9 (27.201)
Average precipitation days (≥ 0.1 mm)	13	12	11	13	13	13	10	9	10	10	12	14	139
Average snowy days	10	7	4	1	0	0	0	0	0	0	3	8	33
Average relative humidity (%)	78	71	63	61	61	63	61	61	67	71	75	79	68
Mean monthly sunshine hours	72.2	101.7	153.2	188.1	242.2	260.9	290.8	274.0	204.3	163.1	97.0	64.5	2,111.9

Figure 43: Climatic data of Belgrade (Rahman, SMM 2018).

comes from south side, bringing cold air with high humidity. This directs the design to take necessary precautions in winter.

The radiation from the sun received by different façade of buildings is crucial in terms of building performance and lighting. Based on solar analysis on each façade, the angle of the shading device can be determined. Moreover, natural lighting level which is achieved in indoor before conducting natural lighting analysis needed to be considered.

4.3.2 Determining of SIAF for building 6

Double skin facade is always a concern of cost. A very careful calculation, thereafter a very fair consideration is needed to decide for a double skin facade. In the case of exemplar building; the climate motivates to decide for a double skin facade system but considering the economy it may not be viable to decide for a double skin SIAF. Though a double skin facade system can give the scope to provide more insulation in interior space. However, the high insulation demands from November to March, these six months to preserve the interior heat. Within rest of the seven months, April and October climate requires moderate insulation. The rest four months require the interior environment away from outside heat. Therefore, sun shading and huge ventilation possibility should be considered. Passive cooling may be sufficient for these four months. However, a mechanical cooling system is sometimes required. Thus a cooling loss circumstances may occur. Therefore, a single skin SIAF is suggested with maximum insulation capability. A single skin SIAF will be applied and analyzed afterward.

5. Refurbishment proposal of building 6

Proposed facade refurbishment design for building 6 is based on the analysis of the existing situation of the exemplar building. While analyzing the exemplar building it has been found that the building 6 is technically sound for refurbishment. Nevertheless building 6 urges for refurbishment. The climatic analysis also concludes with a high insulated single skin facade for the exemplar building. It also has been determined in the previous chapter that a single skin SIAF would be customized and analyzed for the facade refurbishment of the exemplar building.

Building 6 of Block 23 in New Belgrade is a building which carries heritage value. To design the building heritage value stays on top of other factors of refurbishment. SIAF can be constructed with various methods and materials. A careful selection of material of the facade is considered respecting the iconic character of the exemplar building. To do so, less massive, transparent and simple variants has been considered in the design process to create the architectural appearance. In the process of design decision it has not been restrained the present expression of the building rather brighten the existing language while refurbishment. The opportunity of SIAF to set with this concept has been expressed further.

5.1 Design alternatives of SIAF as single skin

SIAF as single skin is identical in outer appearance with double skin SIAF while it will fix as plugin or curtain. A prefabricated system will be bolt with building structure with bracket. SIAF can be fit as ‘in-fill’ system. The total void area in between column, beam and parapet member will be filled with pre-fabricated facade. SIAF can be plugged-in on primary structure with bracket. In this case, the gap between the skin and the primary structure is less than that of double skin option. A clearance is required to move the skin inward. For the both case the rotary mechanism will be place in interior space referring figure 45: (Rahman, SMM 2018).

In the exemplar building the facade solutions has been experimented with above two systems with two material variants. The method to achieve ΔL depends on the used material for shading part. For the case of figure 44 A: (Rahman, SMM 2018), the facade appearance will be as ‘in-fill’. On the other hand the figure 44 B: (Rahman, SMM 2018), indicate the facade appearance as curtain facade.

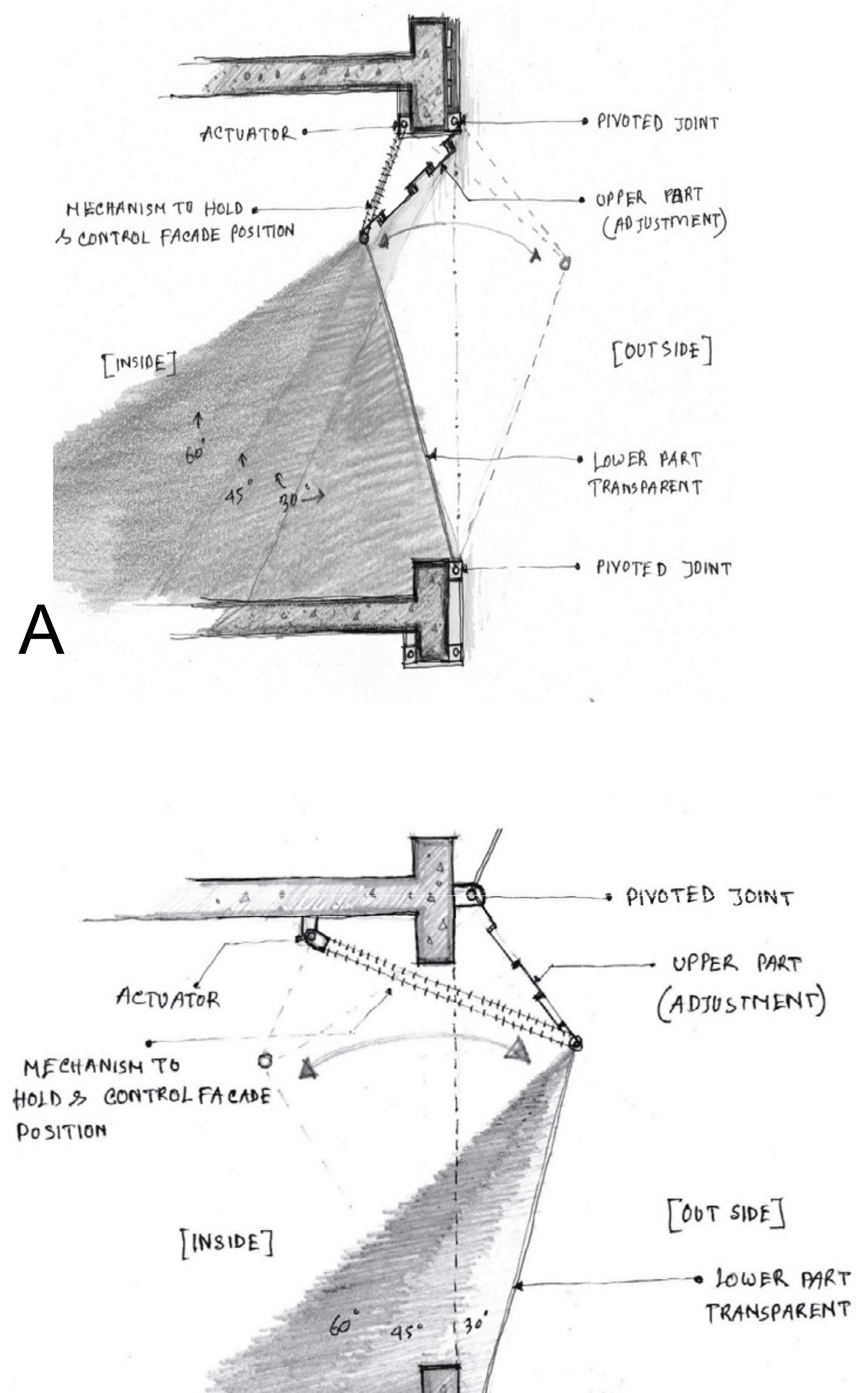


Figure 44 A, B: Schematic Diagram of SIAF as single skin (Rahman, SMM 2018).

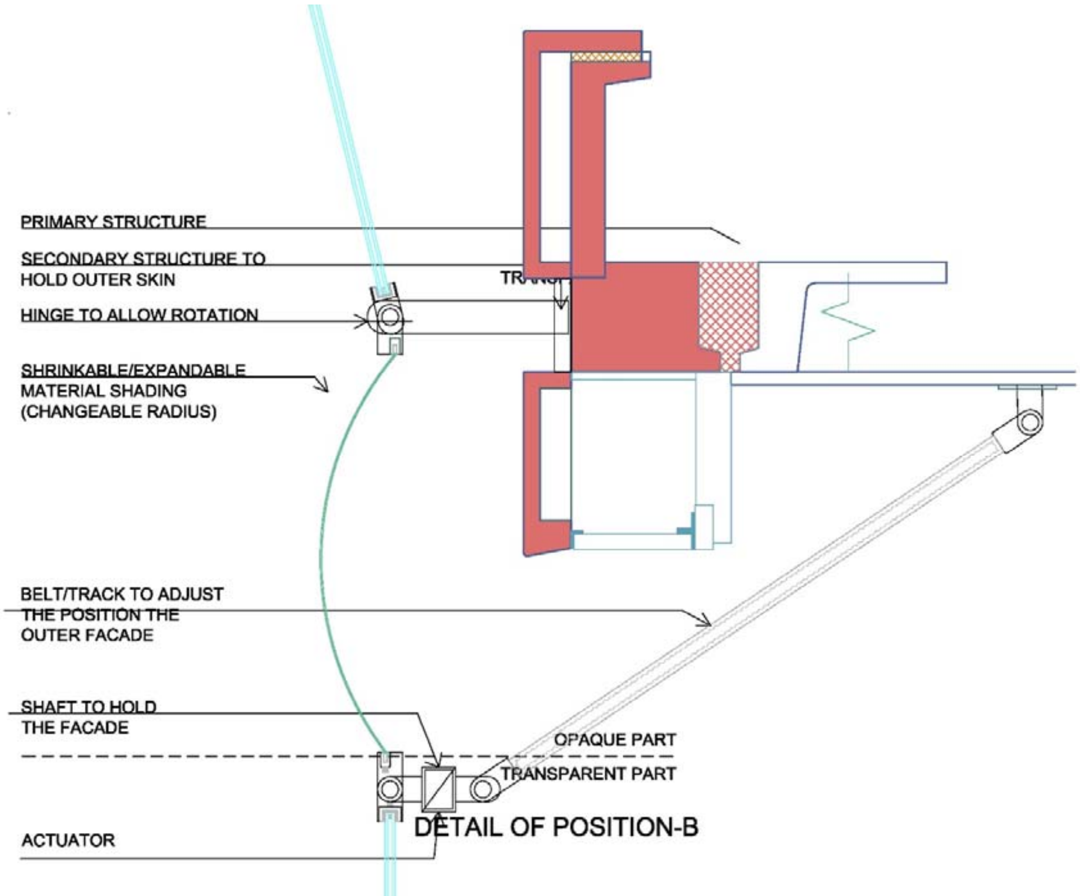


Figure 45: Fixing system of SIAF as single skin (Rahman, SMM 2018).

5.2 Architectural Appearance with variants of SIAF

Figure 46: Architectural appearance with curve metal shading, plugin or curtain method (Rahman, SMM 2018).

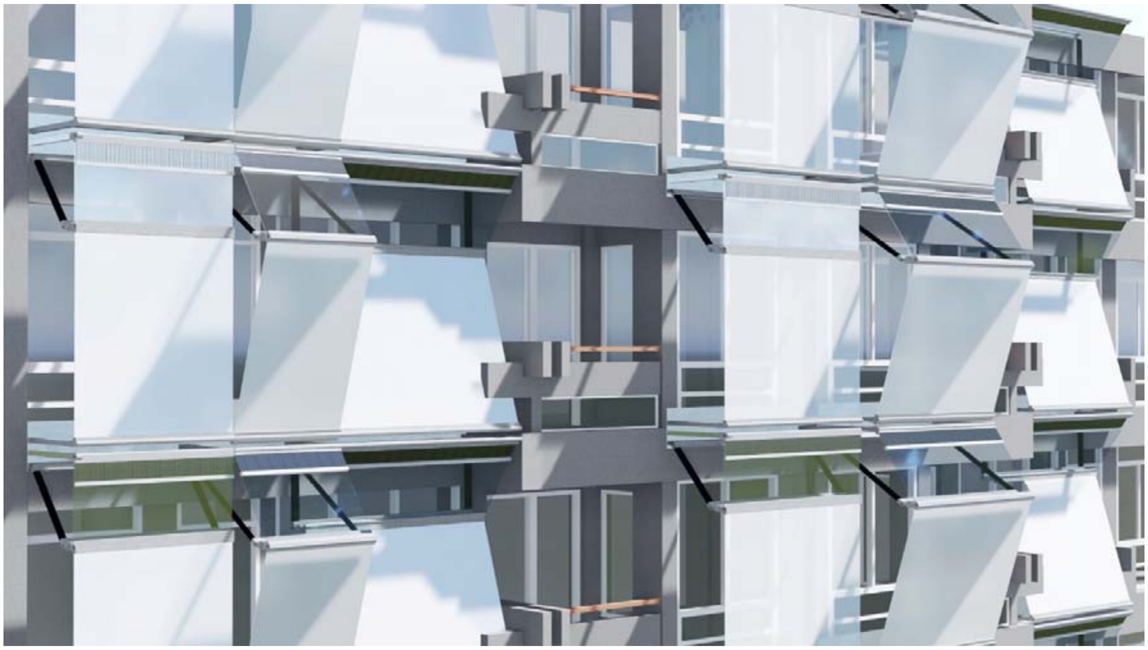


Figure 47: Architectural appearance with sliding shading, plugin or curtain method (Rahman, SMM 2018).

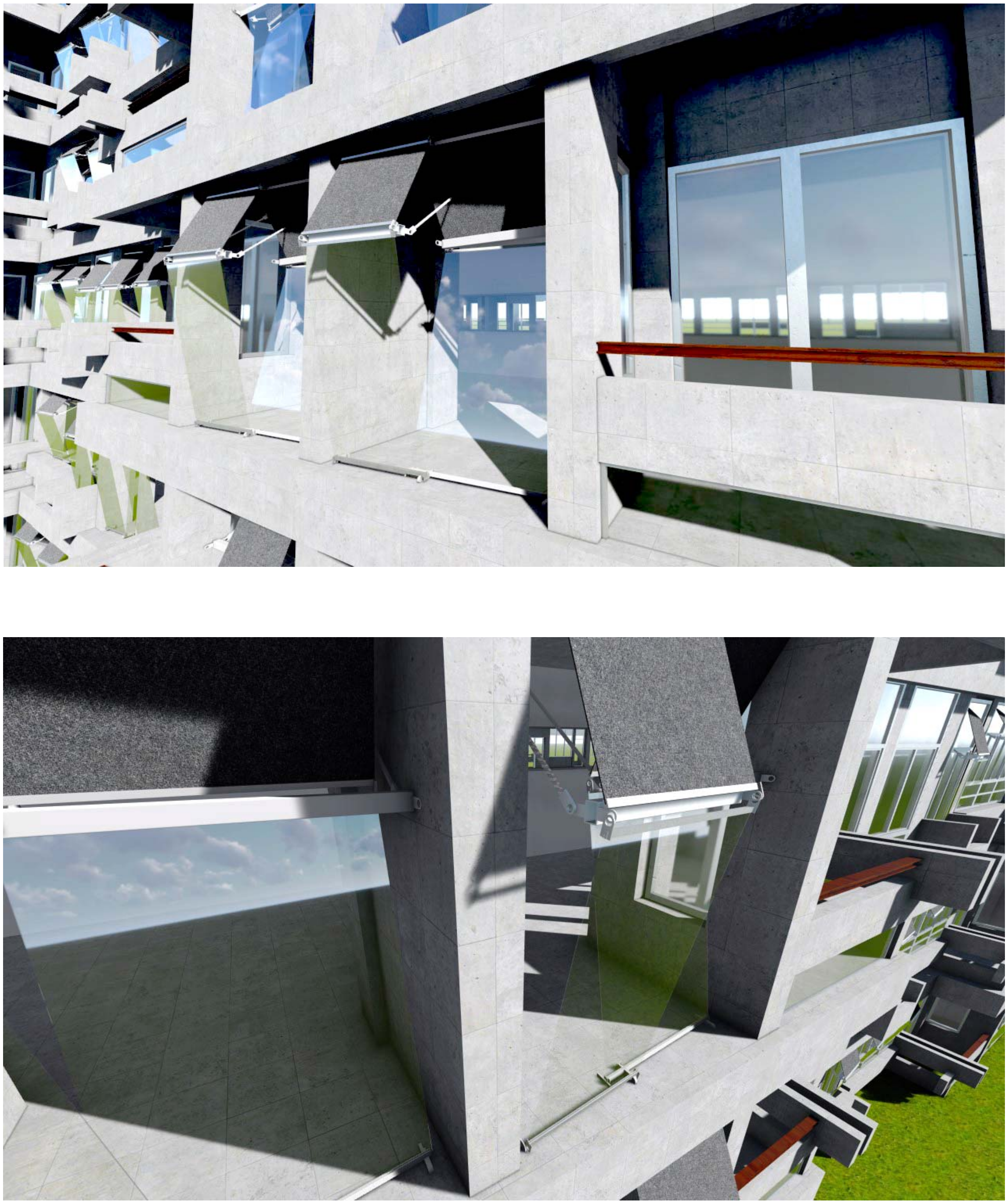


Figure 48: Architectural appearance with roller shading, infill method (Rahman, SMM 2018).

Figure 49: Architectural appearance with curve metal shading, infill method (Rahman, SMM 2018).

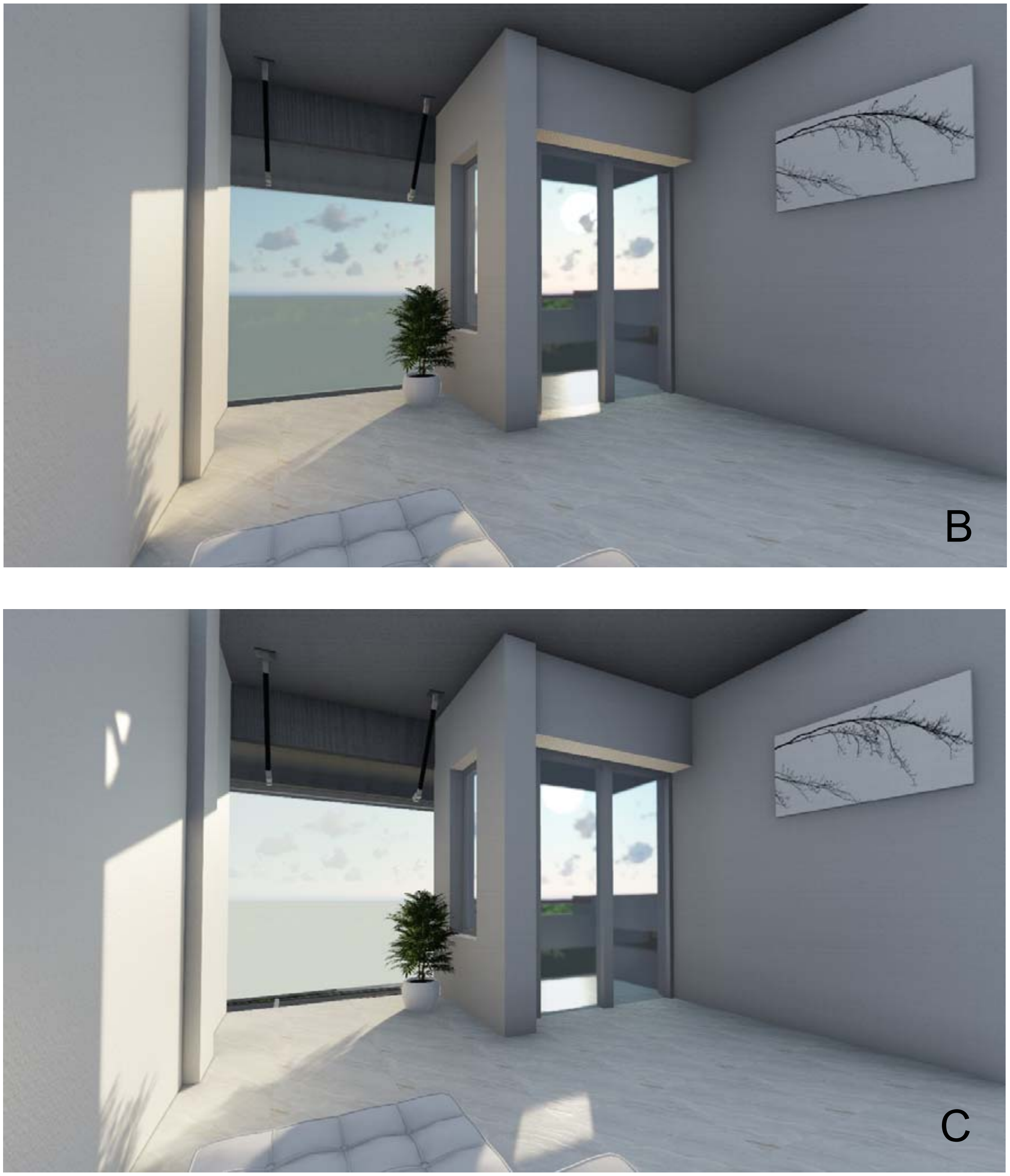


Figure 50A, B, C: Interior appearance with curve metal shading, plugin or curtain method (Rahman, SMM 2018).


A


B

Figure 51: A, B, C Interior appearance with slide glass shading, plugin or curtain method (Rahman, SMM 2018).

5.3 Conclusion

This chapter has shown the architectural appearance after refurbishment with the selected variance of Shading Integrated Adjustable Facade system. The appearance is in a schematic level. Further detailing and rendering can enhance the architectural appearance of the exemplar building. With the image of variants above it can be conclude that referring the figure 47, the variant with sliding glass shading can conceive the concept of design most. A total transparency of facade has been achieved with this system both from the exterior and from the interior referring the figure: 51.

6. Daylight simulation

According to Hopkins (1963) 'Daylight factor (DF) is a daylight availability metric that expresses as a percentage the amount of daylight available inside a room on a work plane compared to the amount of unobstructed daylight available outside under overcast sky conditions'. Mardaljevic (2012) said about the key building properties that determine the magnitude and distribution of the daylight factor in a space are: [16]

- The size, distribution, location and transmission properties of the facade and roof windows.
- The size and configuration of the space.
- The reflective properties of the internal and external surfaces.
- The degree to which external structures obscure the view of the sky.

The Chartered Institution of Building Services Engineers (CIBSE) set a guideline in 2002 about daylight factor. The higher the DF, the more daylight is available in the room. Rooms with an average DF of 2% or more can be considered daylit, but electric lighting may still be needed to perform visual tasks. A room will appear strongly daylit when the average DF is 5% or more, in which case electric lighting will most likely not be used during daytime. [16]

A calculation has been done in the appendix 1 for a building in Germany where it is found that SIAF can control daylight factor from 2.59 for position B (facade inclination toward outside the room) to 5.42 for the position C (facade inclination toward inside the room). Therefore, it can be said that SIAF has an opportunity to control daylight 1: 2.09 while the view will not be hampered recognizably.

The daylight situation has been simulated in 'Revit 2016' software. The location has been considered the city of Belgrade where the latitude = 44.8° and longitude = 20.4667° has been considered to pin point the site location. North direction is 38° anti clock along the longitudinal axis of the building. Thus the experimented room orientation is toward south-west. The altitude is considered 9.14m which is the second floor table height. To simulate this space 16:00 hr. of 25th June, 2018 has been considered. The sky setting is 'ICE clear sky' having DNI=752 w/m^2, DHI=92 w/m^2.

6.1 Daylight simulation for position A

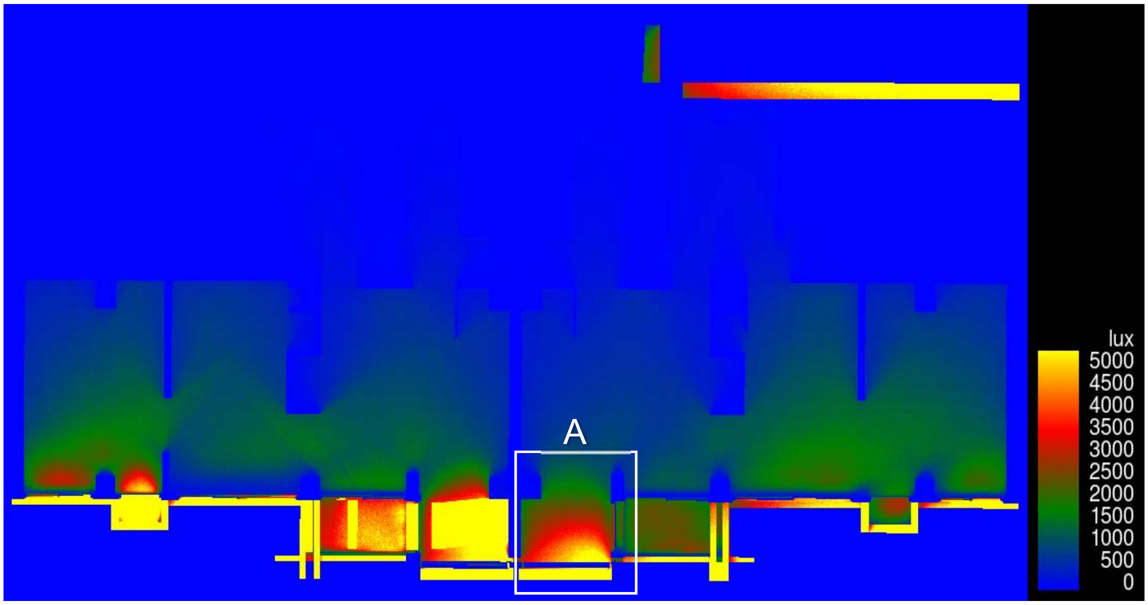


Figure 52: Daylight simulation for position A (Rahman, SMM 2018).

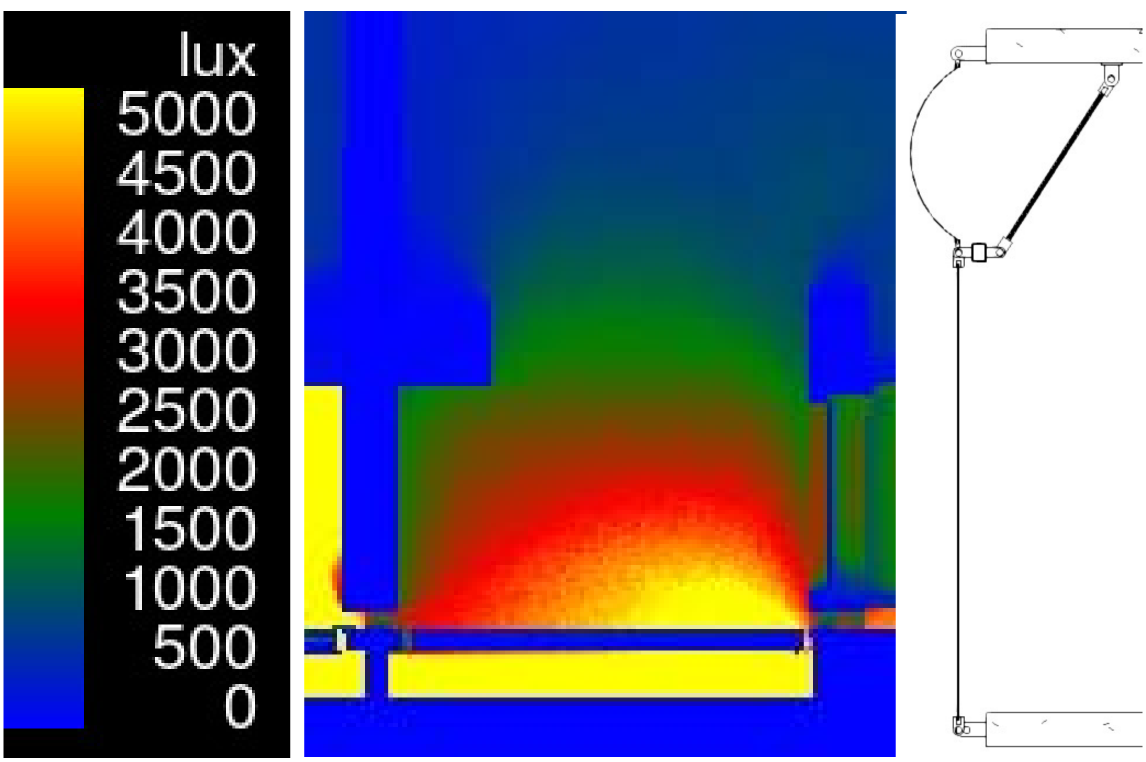


Figure 53: A-zoom of figure 52 (Rahman, SMM 2018).

In the figure 52, 53: (Rahman, SMM 2018) the illuminance shows that the room is lit with 1000 lux to 3000 lux in most of the area and adjacent to the window it reaches up to 5000 lux which is extremely glared area. The illuminance graph has been simulated with the facade position normal shown in the right side of figure 53.

6.2 Daylight simulation for position B

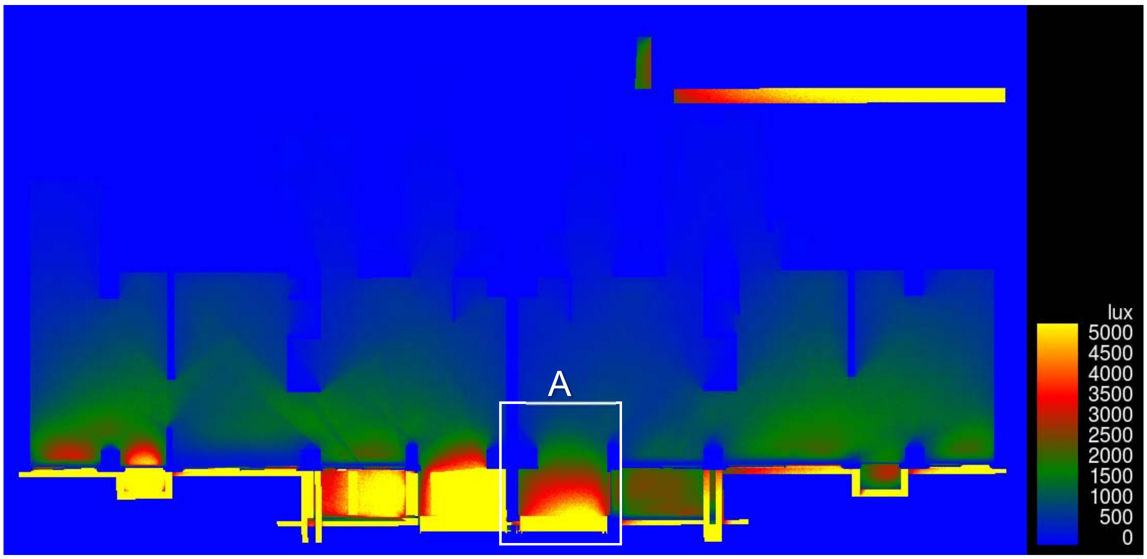


Figure 54: Daylight simulation for position B (Rahman, SMM 2018).

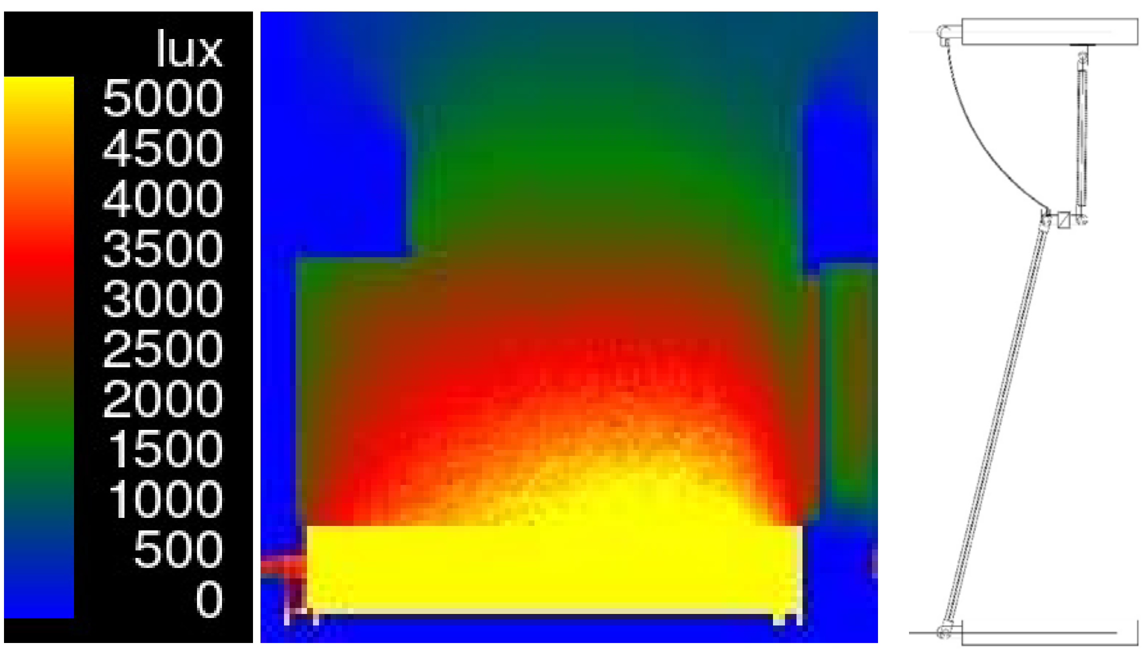


Figure 55: A-zoom of figure 54 (Rahman, SMM 2018).

In the figure 54, 55: (Rahman, SMM 2018) the illuminance shows that the room is lit with 1500 lux to 4000 lux in most of the area and adjacent to the window it reaches up to 5000 lux which is extremely glared area. The illuminance graph has been simulated with the facade position inclined inward the room shown in the right side of figure 53.

6.3 Daylight simulation for position C

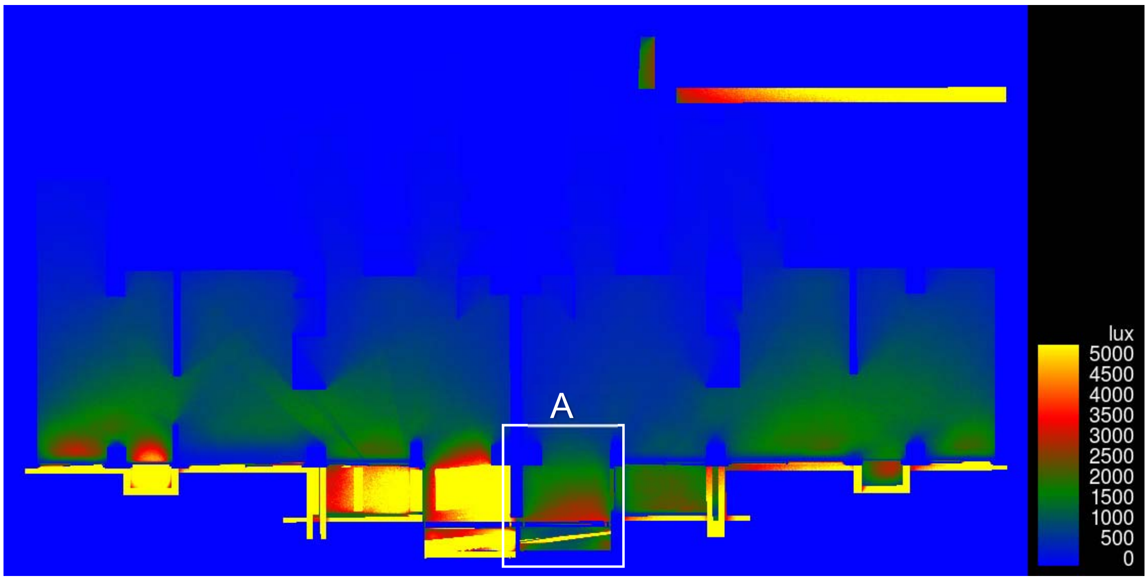


Figure 56: Daylight simulation for position C (Rahman, SMM 2018).

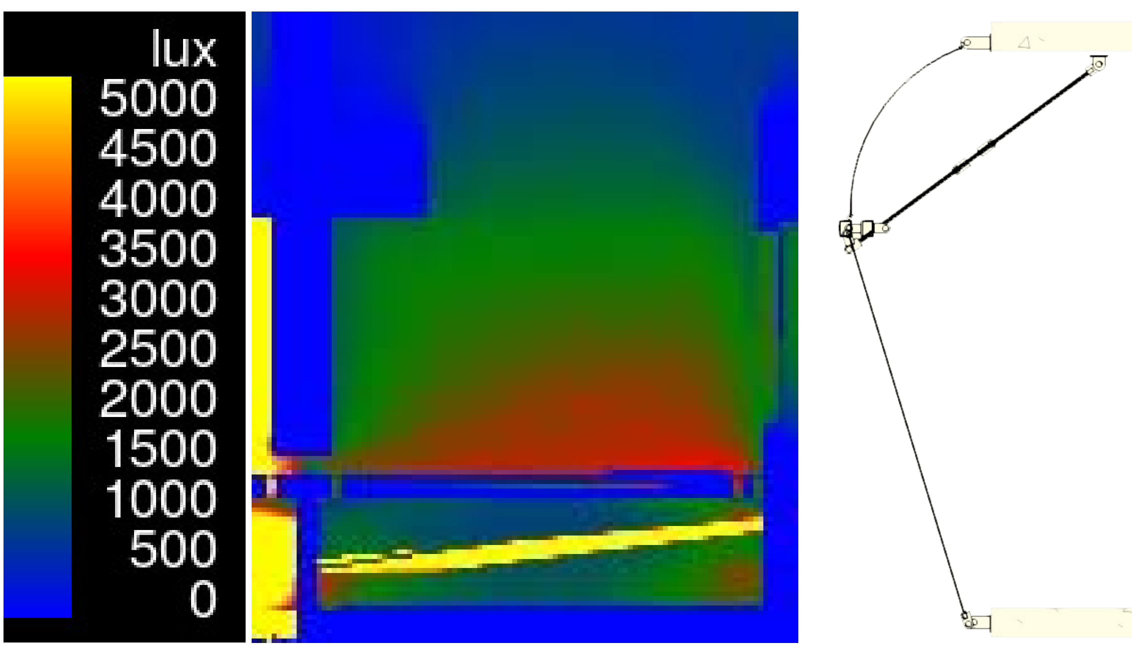


Figure 57: A-zoom of figure 56 (Rahman, SMM 2018).

In the figure 56, 57: (Rahman, SMM 2018) the illuminance shows that the room is lit with 500 lux to 2000 lux in most of the area and adjacent to the window it reaches up to 2500 lux which is comfortable in terms of daylighting and glare condition. The illuminance graph has been simulated with the facade position inclined towards outside shown in the right side of figure 57.

6.4 Comparison

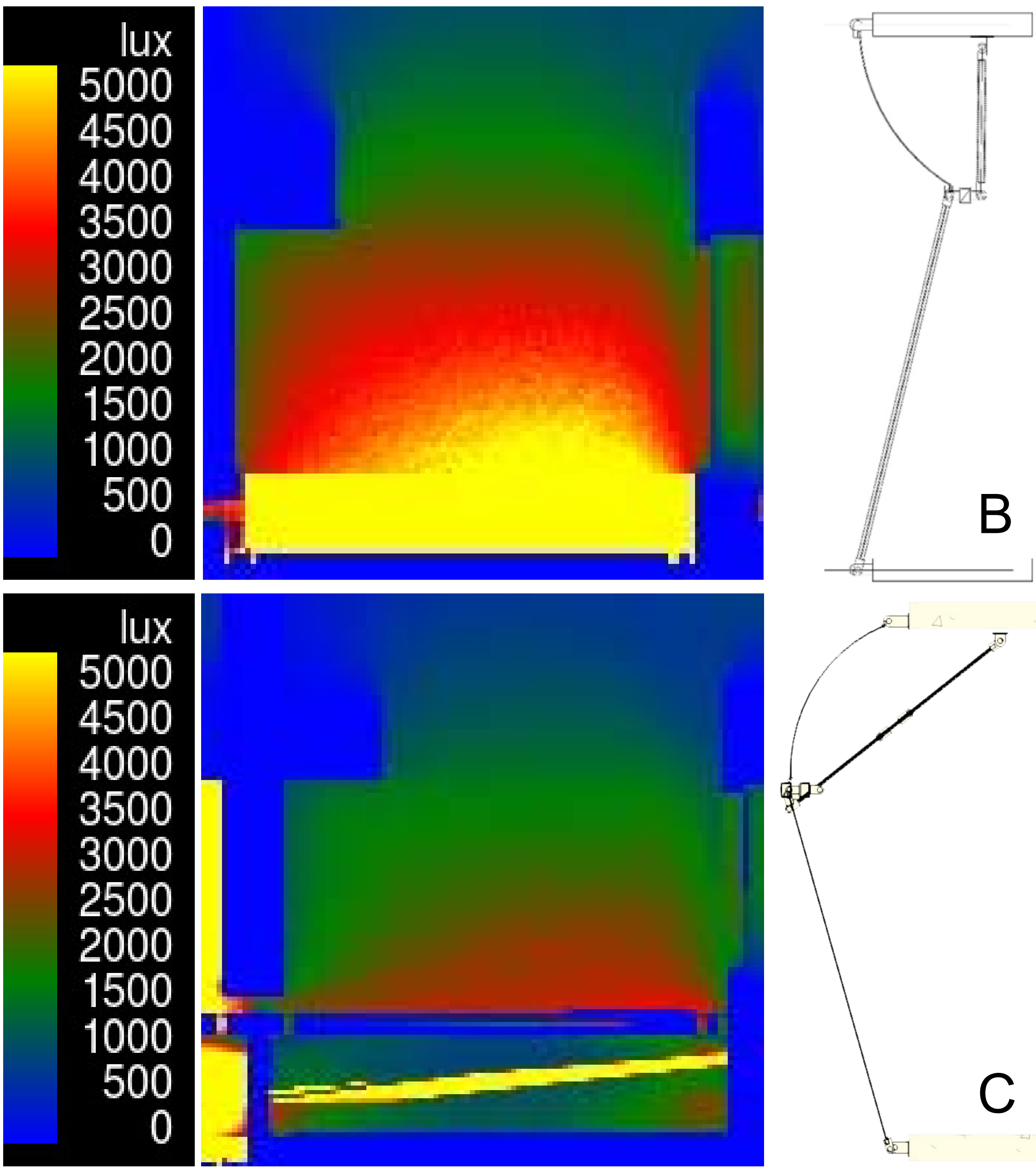


Figure 58: Illuminance comparison between Position B and C (Rahman, SMM 2018).

In the figure 58: (Rahman, SMM 2018), it is clear that in a condition of maximum sunny day the room is quite comfortable regarding illuminance in position C, where the SIAF is inclined outside to shade the room. On the other hand, while shading is not active that means, if somebody want to allow the sun inside the room, the simulation shows in the position B that a flood of daylight is flowing in the room.

User can customize their need of the sun in any daylight condition by operating the SIAF position. It can be said otherwise that; in summer when direct sun may not be required the user can incline the SIAF outward to protect direct sun and in winter they can incline the SIAF inward to allow sun inside the room. In both case user will not deprive of view towards outside. Therefore it can be said that a SIAF system has vast personalization opportunity regarding improving daylight condition in the room. Moreover, all the time it will ensure users view towards outside.

7. Conclusion

7.1 Conclusion

The concrete block is a witness of time and need. Perhaps it will be a ruin or it will be a vibrant place having all modern facilities and amenities with all the contemporary concern in the city of New Belgrade. The Building 6 of block 23 conceive people's emotion throughout half a century. The people does not want to let the building become ruin rather they want to see their memory embedding in the building. They want to use the building as contemporary epoch. Does the building itself have the aptitude to deliver this demand of people! In a word 'yes'. It has in an excellent order to accommodate all kind of refurbishing arrangement. The unique IMS structure let it happened even after passing half a century. The IMS system in which the Building 6 is constructed is justified with a kind of systematic approach of refurbishment called Industrial Building Model or IBM. The IBM has expressed the full potential of refurbishment of the Building 6. It also has been justified that how much invasion is required in various level of renovation. In a technical aspect the Building 6 has the all compatibility to adopt the refurbishment operation. The refurbishment extent may happened from the spatial arrangement of interior up to the facade refurbishment.

In the course of time while refurbishment is not only a physical demand of building 6 but also a social demand for the users of new generation. In this occasion, increasing the architectural value is a concern. Spatial rearrangement is mainly a physical factor. To increase the architectural quality of an interior space daylight is a vibrant feature to design with. Daylight is an integral part of Architecture. It is not possible to create an Architecture without daylight. Designing of daylighting is nevertheless one of the most sophisticate part of architectural design process. This is because, daylight influence on human physical activity as well as on human emotion. Along with the daylight view is a quality of space which deals with completely user's psychology. View is unique for each site and for each space. It is as unique as a person. Along with daylight dealing with view is a state of the art architectural sophistication. All the contemporary great architecture has its great daylight experience and obviously great view towards outside. View emotionally bond users with architecture.

To find out the optimum position of daylight factor is crucial and critical. SIAF has the potential to control daylight dramatically while uncompromised with view towards outside. It has the flexibility to personalize in a wide range regarding daylight control. Nevertheless, SIAF is a slim and smart solution of facade which can also install in a smart way of the least invasion on primary structure. Just screw it on to the structure like a device and use it. SIAF ensures view while shading interior space.

A great architectural appearance can be achieved with some variants of SIAF especially with the sliding glass shading. It is the most transparent and thus elegant. This variant is well suited with the iconic character of the Building 6, widely with the New Belgrade 'Mass Housing' envelop. Try it!

7.2 Internationalization of SIAF

Throughout the thesis it has been tried to justify in various scientific way the flexibility and personalization capability of SIAF. Technically it is simple to add-on. It has the option to use as double skin or as single skin and with double glazed pane or single glazed pane. Moreover, the shading part can be designed in four method with lot of material variants all with any color variant. Therefore, SIAF has the ability of personalization as each individual. Inter climatic zone of the globe are required different types of facade solution. Moreover, intercultural people has different taste and likings. Shading Integrated Adjustable Facade is a system which can meet up all the demand. For an example, in the tropical climate where the temperature difference in between day and night is less as well as the average temperature is close to human comfort level (26°C) and where insulation requirement is less; single skin single pane SIAF can be prescribed. The thesis already justified the SIAF in the exemplar building the humid sub-tropical climatic zone of south-eastern Europe, where an insulated double pane single skin facade has been proposed. Continental and sub-arctic or in desert climate, may use a high insulated double skin option.

Therefore, SIAF is an international solution with vast adaptation possibility. It can conceive the iconic character of buildings in inter personal, inter cultural, inter climatic and international context.

7.3 User’s feedback

Whatever is the design is, users are the consumer of the final product. As architecture is expensive to build a real scale mock-up for the users to justify their opinion and suggestions. However, there are alternatives by which the architecture can be perceived. Three dimensional appearance is one of the media which is perceivable by users. Other data also like compared simulation results also helpful to them to perceive the specific condition of the building. In this thesis, energy and daylight simulation of existing condition has been done. Moreover the daylight simulation of various proposed condition in various position of facade has been done and compared. This compared data along with the architectural appearance of them can be cumulated and presented to the existing users to take their opinion. This opinion can be used for the further development of the proposed envelop of the exemplar building.

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Figure 8: Petričić, B 1962, Federal Executive Council's unfinished building, 1960s. Original source: Urban Planning Institute of Belgrade. Adapted from https://doi.org/10.3311/PPar.11621. [24 April 2018]

Figure 9: Ahlgren, J 2016, Columnated space in ground floor- Building 6 Block 23, New Belgrade, digital image. Adopted from https://www.flickr.com/photos/71588975@N05/sets/72157674382545716/. [12 May, 2018].

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Figure 12: Rahman, SMM 2018, Cross section of apartment; daylight and view.

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Figure 14: Rahman, SMM 2018, IMS system: (a) Skeleton fame consists in concrete column, pre-stressed beams, cantilever slab, edge rib; (b) Slab to column joint; (c) Top view of standard floor slab; (d) Column joining with foundation. Adopted from: Nikolic J. (2018) 'Building "with the Systems" vs. Building "in the System" of IMS Open Technology of Prefabricated Construction: Challenges for New "Infill" Industry for Massive Housing Retrofitting', *Energies,* 11(5), 1128.

Figure 15: Rahman, SMM 2018, Schematic view for systematic approach according to independent functional and technical levels, IBM massive structure hierarchy. Adopted from: Nikolic J. (2018) 'Building "with the Systems" vs. Building "in the System" of IMS Open Technology of Prefabricated Construction: Challenges for New "Infill" Industry for Massive Housing Retrofitting', *Energies,* 11(5), 1128.

10. Appendix

10.1 Appendix 1

Daylight factor calculation

2.2. Calculation

2.2.1. Consideration of space

Since the green building is an open floor office building. Here I considered the effective size of 4.0mX3.0mX 2.8m. In the picture-03 it is considered, the floor is in second level and façade orientation towards west.

This calculation finds the mean daylight factor in the office. Initially with only the original obstruction is building. Assume that the internal reflectance is: ceiling 0.7, wall, surfaces 0.4, floor 0.2.

Ag= 6.75m2

A = 59m2

Area of enclosing room surfaces Ceiling (12 m2) + walls and windows (35 m2) + floor (12 m2)

$\theta =$ 32' [picture-04, for position-A]

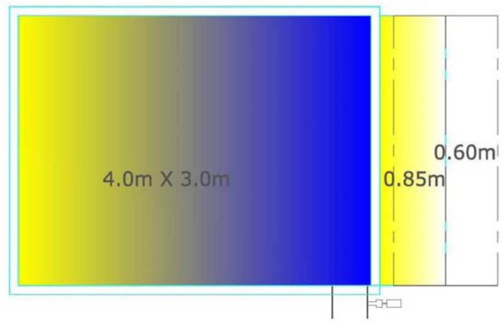
Considering no obstruction in lower level

$\theta =$ 67' [picture-04, for position-B]

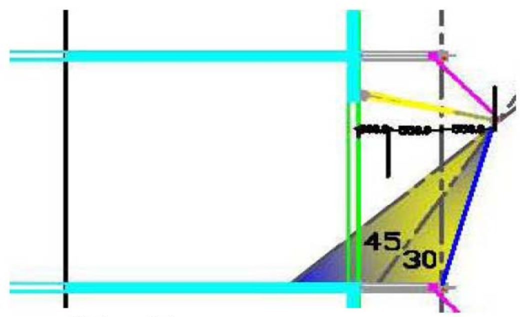
Considering no obstruction in lower level

$\tau = 0.6$

Transmittance of glazing 0.75 (diffuse transmittance of double glazing) x 0.8 (maintenance factor)

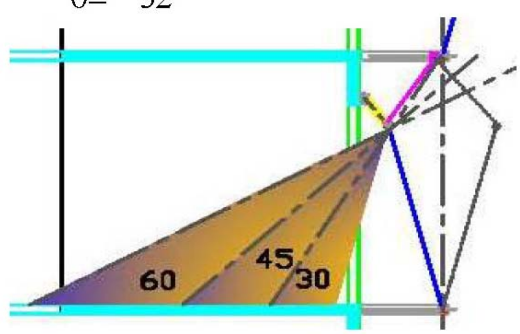


Picture-03
Horizontal section for the considered room



Picture-04
Vertical section – position A

$\theta =$ 32'



Picture-05
Vertical section – position B

$\theta =$ 67'

p= 0.39

Mean reflectance of room surfaces based on reflectance of ceiling, 0.7; vertical surfaces excluding windows, 0.4; window glazing, 0.1; floor, 0.2

The room reflectance is an area-weighted mean. That is, each surface area is multiplied by the corresponding reflectance, and the total of these is then divided by the total area.
(12*0.7+12*0.2+(14*2.5-6.75)*0.4+6.75*0.1)/59= 0.386

Then using equation

$$\overline{D} = \frac{A_g \theta \tau}{A\,(1-p2)}$$

= 6.75X 32X0.6/59/ (1-0.39X0.39)

=2.59 for the position A

Again for position B

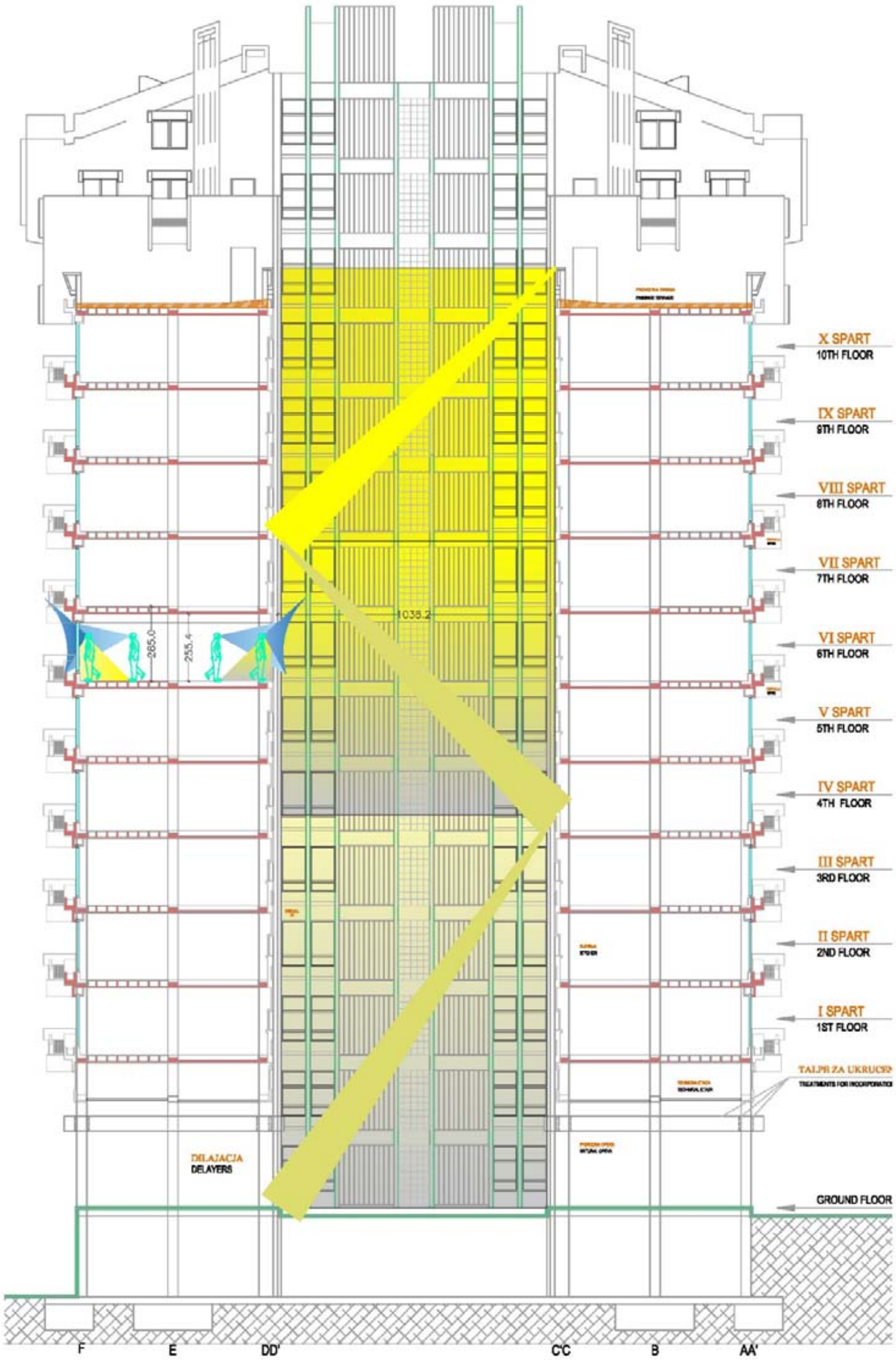
$$\overline{D} = \frac{A_g \theta \tau}{A\,(1-p2)}$$

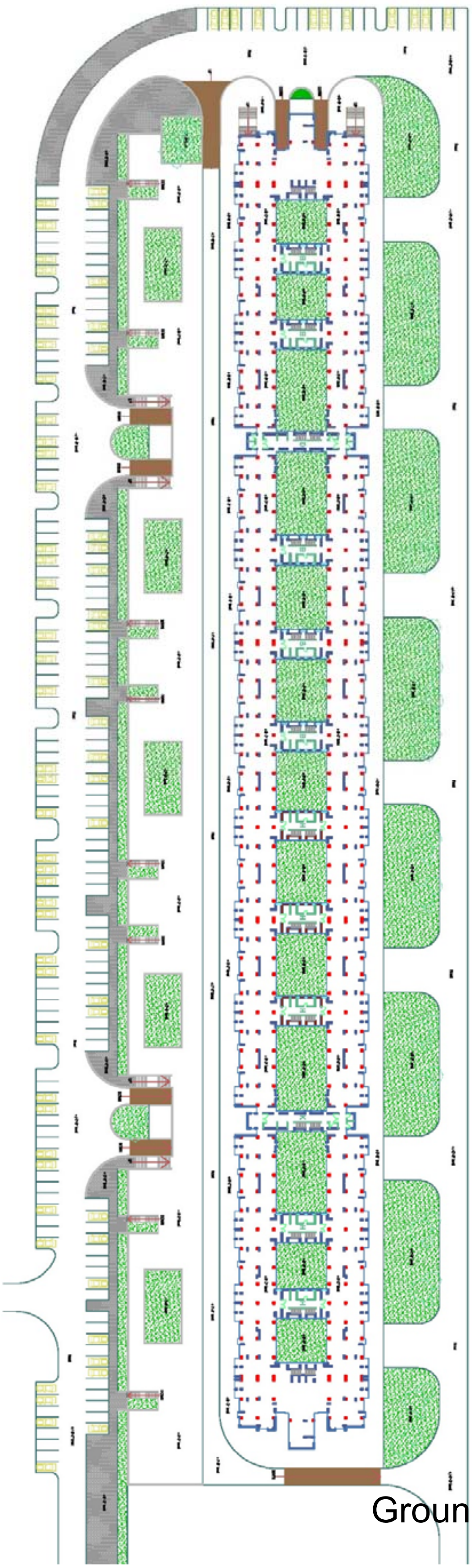
= 6.75X 67X0.6/59/ (1-0.39X0.39)

=5.42 for the position B

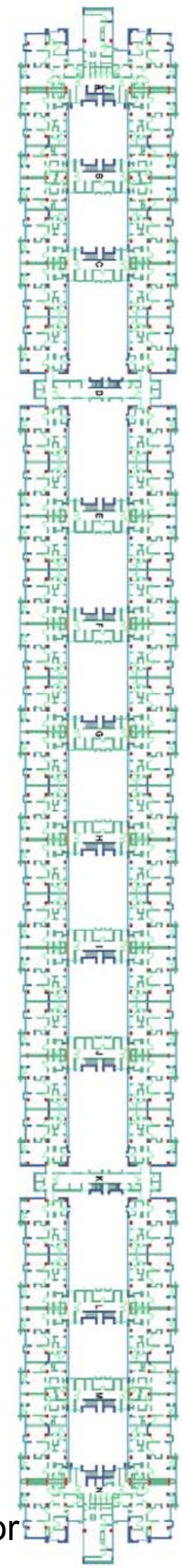
10.2 Appendix 2

Drawing based on the original drawing.





Ground Floor



Typical Floor