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Derivation of a Design Solution for the Conservation of a Historical Payab in the Redevelopment of Doloeei, Gonabad

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ABSTRACT

This paper aims to demonstrate the conservation process of historic underground water access or Payab by proposing a multistage decision-making design in Gonabad city, northeast part of Iran. The Payab was in the center axis of a street in the proposed development of a new road which appeared to be against the new construction. The challenge was to develop the new road in the central axis without disturbing much the historic structure in the location. Hence, a request was made to keep both the new road and the historic Payab structure with a design solution. In order to tackle the design solution requested, a qualitative methodology was designed by way of site surveys, site documentation, graphical analysis and interviews. The findings of the research demonstrated contradicting opinions among the governors-laypeople, youngers-elders and males and females about the historic structure. Based on the findings, it was proposed that a protective shield, which aimed to conserve the historic structure under the weight of the new road is required, with a new entrance to be provided through an adjacent sidewalk to achieve consensus among those of diverse ideas. As a conclusion, conservation projects as demonstrated in this paper, like any other conservation projects elsewhere are faced with budget limitation, poor planning and the support it needed. As the historic structure has been part of the local built environment, the integration with other architectural elements in the context is of paramount importance to support the sustainability of the local built environment.

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1. Introduction

Conservation, preservation, and rehabilitation of heritage areas have been multidisciplinary, multidimensional, and interdisciplinary projects and somehow tough task for designers to plan in the developing countries. This kind of project divides developers, users, politicians, experts, people and academicians with different expectations, experiences and believes. In this dialectic of time and location, budget and value, tradition and modern, to be or not to be the historic elements, the new generation of buildings, urban textures, and urban forms thus regenerate.

Studies showed that the historic sites, buildings, and elements have been faced with problems, challenges, and threats from both natural hazards and manmade interventions in the whole history. The natural hazards affected based on the low level of maintenance, budgeting, and financing, additionally, manmade based on the unclear policies, strategies, and implementing tactics (Brimblecombe & Grossi, 2014). Despite publication series of guidelines and design toolkits by UNESCO, and heritage

organization in all counties, it seems still needs to specific study, research, and investigation for localizing the culture, knowledge, and approach of conservation.

Iran as a country with both long and wide background of history has been faced with conservation projects with various aspects. Some conservation projects in Esfehan, Kashan, and Yazd were implemented, for other cities and places some plans were provided such Gonabad, Syraph, and Qazvin (ICHHTO, 2016), and some of the site, buildings, and elements still are needed to a conservation project. However, this process always has been confronted with prioritising, financing, and budgeting as more challenging aspects of conservation in the country.

2. Problem Statement

Gonabad city is a historic city with a long background in the northeast part of Iran. The historic part of the city was documented, and the plan was approved (Tafahomi, 2010). The historic structure of the *Payab* (under-ground-water-access) was not included in the documentation project due to the budgeting and timing. In addition, this area of the country did not document in detail, and information was limited to some reports and books (Tabandeh, 1969; Zamani, 1994) with a large scale of the study. So, in those references just could be observed some general statistical data about population, political circumstances, and geographical aspect in the regional scale. Therefore, in the architectural scale, the resources have been so limited.

The *Payab* is located in the middle part of the Daloei in the suburb of Gonabad city. This historic structure has functioned in adapting with the contextual and the cultural aspects of the daily life to access to the water in the desert wasteland due to the significance function the Qanat (underground water system supply) to support horticulture, agriculture, and settlement in the area. The *Payab* was the access point to the traditional water supply system for everyone particularly for homemakers when it passed the inhabitant areas; however, males consumed the water in the surrounding farms for cultivation and horticultural activities. Nevertheless, with the new water supply system in the city, the functionality of the historic structure decreased, and it no longer play the same role as it was in the past. However, females preferred to use this structure as a behavioral sitting (Gehl, 2007). Surprisingly, the new proposed road was projected to pass through the heritage structure in the central part of the area, without paying any attention to the historic background, functionality, and acceptability of the historic structure for both government and governance (Harris & Dines, 1998). Importantly, the local government did not accept to revise on the direction, form, and sections of the new road, due to the approved plan in the bureaucratic process. However, other precedents addressed designing and engineering solutions for those historic elements as the central point in the road with structure of square, roundabout, and open spaces (French, 1983; Krier, 1991; Antoniou, 2002) to conserve the historic or heritage element in the location. Nevertheless, the transport engineers did not plan such kind of innovation to respect to the historic structure. Hence, the clear request was to keep both the new road and the historic structure with a design solution.

3. Theoretical Framework

Cities have produced urban textures, fabrics, and forms based on the environment, culture, and history in the development process (Benevolo, 1980; Altman & Chemers, 1984; Radoslav, et al., 2013; Shin, et al., 2015). Especially, the historic cities have been included varieties of architectural elements from different times and eras those could introduce as the symbols of transition process of the urban evolution (Morris, 1994; Tafahomi, 2007). In this process, some of those architectural historic elements replaced with new elements in the process of renovation, reconstruction, and redevelopment (Radoslav, et al., 2013). However, the influence of the replacement of those historic elements has affected the memories of laypeople with the new image of the city that adaptation with the new forms has not been easy for users although users may not recognize this process in a short time (Llopis, et al., 2015).

Every historic city has encompassed the specific historic elements those recognized as the heritage and characteristic elements in the city. Those characteristic elements have included both physical and nonphysical elements as a part of the character of the city. For this reason, in the more documents in the urban design, urban planning, and landscape design have been emphasized the keeping those characteristic elements (American Planning Association, 2006; Llewelyn-Davies, 2000) in term of the identity of place (Relph, 2007). However, this has not been easy action. For example, other researches demonstrated that planning and design for heritage areas were frustrated with constraints of municipality budgeting for this kind of projects (Raymond, 1984; Means, 2004).

Nevertheless, the heritage, conservation, and preservation have been a critical issue in all countries and the motto of the EU as "Discovering the Past, Shaping the Future" (Heritage, 2005) could demonstrate how the conservation has been significant. However, activities in the conservation areas have been somehow separated and did not document well in the world. For example, in the study of Brimblecombe & Grossi, they emphasized that if there were some; they did not convert into policies, strategies, and implementation tactics (Brimblecombe & Grossi, 2014) in both natural hazards such as earthquakes, flood, and runoff, and manmade intervention such as poor maintenance, vandalism, and demolishing. However, remarkably, in those available reports on the precedents earthquakes in the area did not observe any cases about damaging or destroying the underground structures.

The conservation in the country mostly has tended to the protection than conservation due to the background, however, some projects in the Yazd, Kashan, and Esfehan have been oriented to the rehabilitation for some touristic proposes than historic (Tavasoli, 2000). In this alignment, studies released using of traditional materials and technology in the conservation, rehabilitation, and vitalization project have been in the same orientation with the resiliency of project in the context than an integration of new materials (Amicoa & Curràb, 2014). In detail, some researches, studies, and rehabilitation projects on the historic cities emphasised this approach in the country as well (ICHHTO, 2016).

In addition, some precedents suggested applying the participatory design for more effectiveness results (Manzini & Rizzo, 2011; Hussain, et al., 2012; Iversen & Dindler, 2014). This process has tended to collaboration between designers, users, and stakeholders (Hussain, et al., 2012), in the whole process of design. Indeed, in this process, researchers have recommended shifting from the final product to the social production approaches (Manzini & Rizzo, 2011; Iversen & Dindler, 2014). In addition, some the researches have reformulated the participatory design into co-design and co-creativity phrases (Sanders & Stappers, 2008). However, application of this approaches has been faced with difficulties in particular countries (Raymond, 1984), and sometimes participation of people resulted in chaos (Hillier, 2002). Nevertheless, this process has facilitated the decision making (Dyson, 2004) but have not been any guarantee of decision taking.

4. Methodology

The methodology of this research was designed with the qualitative method (Dandekar, 1988; Groat & Wang, 2002) with approach of the research through design (Faryling, 1993) and application of observation (Silverman, 2004; Neuman, 2006), interviewing (Neuman, 2006), photography (Llopis, et al., 2015; Tafahomi & Nadi, 2016), and graphical analysis (Dandekar, 1988; Laseau, 2000). The data was combined through site survey, precedents analysis, laypeople perceptions, and overlaying of analytical data. For this process, first, the photogrammetric map updated with physical elements in the site such as the structure of the *Payab* and the new road in the micro-scale (Moughtin, et al., 1999; Miller, et al., 2004). Then through photography (American Planning Association, 2006) the position, condition, situation and visual quality (Bell, 2004; Bell, 2008) of the historic structure documented (Tafahomi, 2009; Tafahomi & Nadi, 2016). Then, the physical condition of the *Payab* measured and documented with metric survey (Groat & Wang, 2002). The interview was included both governmental bodies and laypeople including four groups of male, female, youth, and elder people (Silverman, 2010). Through of those discussions with respondents were discovered the sense of place (Dondis, 1973; Pallasmaa, 2005), perception (Altman & Chemers, 1984) of the structure in the wider landscape (Deming & Swaffield, 2011).

4.1 Case of Study

The *Payab* in Daloeei located in the Historic part of Gonabad city in northeastern part of Iran. The history of the city referred to the around 200 B.C however, all historic aspects were destroyed in three intensive earthquakes. Just those ancient Qanats could refer to the old historical aspects of inhabitants in the area. Therefore, all architectural heritage elements belong in 1100 A.D and after that (Ghirshman, 1954; Tafahomi, 2010). The *Payab* located in the one of the pre-urban areas with the direct connection to the bypass of the city. The new proposed road as redevelopment project scratched the face of the historic fabric through passing in the central part of the area without concerning the historic structure. The historic structure has been the most important heritage element in the area, however; there was not any archaeological investigation or research to discover other sites due to the limited budget for historical research. The project requested based on the proposal of laypeople to warn the local manager for renovation, rehabilitation, or conservation.

4.2 Site Survey, Data Collection and Analysis

The analysis combined from several techniques, data, and processes. In the survey, physical size and the form of the *Payab* were estimated through observation, measurement, and recording. The observation included two groups of the data including first the physical elements particularly applied materials, scale, and technology in the structures, second behavioral patterns of users. This observation was not limited to the historic structure; however, other similar structures in the surrounding areas were surveyed.

The site survey took place on-site for two weeks with visits arranged either in the morning or in the afternoon. The *Payab* was located in the courtyard of an old mosque that with the road expansion, it automatically shifted in the middle of the new road and surprisingly the consulting company never took into account the heritage structure in the designing of the new road. The structure was damaged by the heavy road constructions machines, the entrance destroyed, and the accessibility was so difficult. The roof skylight-visors filled with construction materials based on the soil operations on the road and the inside of the structure was so dirty, dark and unsafe. The entrance was full of wastes and rubbishes.

The size of the structure was 4m height, 4.5m width, and 7m length. The structure was constructed with bricks and carves form of arch as the roof structure. The entrance was not part of the foundation of the structure, but it was an additional element. According to the form, shape, and material of the bricks in the historic structure and the stairs of the entrance, it was clear that the entrance and steps reconstructed. The *Payab* included one entrance, two retables for candles lighting and shelf, two filled skylight in the roof, some traces of four broken stone seats, one channel of water, and two small ponds in the water streams.

Materials of the structure were bricks but some part particularly the roof part covered with stucco and lime mortar several layers due to adaptation with water wetness and moistness. The ground was covered with varieties of materials and mortars, so the recognition of the original materials without an excavation and archaeological operation was impossible. However, the stream of the water channel was paved with some red stones blocks those have been available in the surrounding mountains.

Temperature surprisingly was so calm and comfortable in the structure. The temperature and humanity measured with the electronic thermometer four times. It was from 25 to 28 centigrade and humidity was around 80 that this condition was understandable due to the filled skylights in the structure that it has limited the ventilation and circulation of the air through the hole. In the discussion with local people, they expressed that the atmosphere of the *Payab* has been more comfortable than outside in both hot summer and cold winter. Certainly, this comfortability specification has been one of reason to choose this position as one of the behavioral sittings by females as a hangout. In addition, the song of the water all the time like a music background could help them for more relaxation.

Observations were simultaneously made for two weeks with visits arranged either in the morning or in the afternoon. The purpose was to visit the historic structure, other adjacent structures,

behavioral patterns as well as activities. No activities at all in the surrounding of the historic structure and the new redevelopment construction as the central road totally changed the lifestyle in the area as the photos in rows 1-5 in table 1. The area was similar to a construction site, so no female activities observed, but in the other precedents could be observed how female using of the *Payab* as a behavioral sitting as the row 6 in table 1.

For example, in other precedents in the area, there were some short and rough stones as benches for sitting and using water and more light from the entrance. Inside of the structure, the pattern of activities was based on a few numbers of users in the same time due to the small size of the room. Therefore, maximum ten users were able to attend in the structure at the same time based on the design, but current situation just allowed maximum five users. The attendance of users has not been randomly but based on the relativities, neighbours, and friendship arrange the group of users due to the discussion with users and elders. According to the user's explanations', enter to the structure was always free for the females but for any male just allowed with permission of female users as a traditional value.

The physical activities were included washing large-scale materials such as carpet, blankets, and dresses, or pots. The washing was not just as compulsory activities but a conversation, chatting, and social interactions were more important in the location. Some of users just participated for chatting not any physical activities particularly elders, and sometime smoking of cigarets in the tropical climate without public demonstration.

In the visiting of the surrounding area, in some precedents, some kinds of the material recognized as available, affordable, and durable materials. The surrounding area included some hills and mountains those included red stones as the one of the traditional materials in the area. In addition, the jujube trees have been one of common medical and fruit trees in the area that the wood applied for column, charcoal, and carpentry with strong and dark brown colours. In addition, it was produced fired bricks in the area; however, the price was more expensive than imported one.

Table 1 Survey Results of the Historic Structure

Criteria	Condition	Photos	Architectural Problem
Accessibility and Entrance	The accessibility to the structure was impeded by the construction activities with the entrance destroyed.		The structure totally located in the road centre, with keeping the location, as it was, however, the entrance could not be in the road.
Physical Specification	The physical structure of the *Payab* particularly the paving also damaged due the erosion and low maintenances.		Both flooring and paving of the area were deepened on the level of intervention in the structure
Quality of the Texture	The internal part of the structure is covered with stucco and lime mortar those are not decorative and are not protective.		The coverage of the structure did not demonstrate any static or decorative aspects and it can be replaced with other materials or using the original type of material
Visibility and Legibility	The entrance and physical traces of the structure destroyed. In this condition, the reference pointing character of the *Payab* was also damaged.		Entrance cannot be in the streets; it should be shifted to the juxtaposition part of the sidewalk.
Functionality	The condition of the structure could not provide usability, functionality, applicability similar with the previous times.		Both inside and outside of the historic structure affected the functionality. Therefore, both sides needed to design solutions.

Activities	Those damaged seats, entrance, and stairs could not attract the original users.		The interior space should design to adapt with need, desire, and expectation.

Table 2 Summary of the Key Ideas by the Respondents

Respondents	Observation	Requests
Local manager	- Low quality of space - Low number of tourists - Stopping the construction project	- Renovation of the structure - Upgrade it as a tourist attraction
Governor	- Construction of the road should stopped - No satisfaction among laypeople - Budget problem	- Keeping the historic element - Rehabilitation of the area - Creation tourist attractions - Conserve the historic structure - Renovate
Councilors	- The construction takes a long time - No policy for renovation or conservation - The damage rendered the structure useless	- Renovate the structure - Build the road - Make prompt decision
Heritage officer	- Unregistered heritage element - Limitation of budget for more research - Claim of people about the road - No support from the central government for conservation of the area	- Conservation of the structure without any renovation - Open the road - Guarantee no damage to the structure - Pass the road on the structure
Laypeople Males	- The *Payab* has been a female area - It is no longer important -	- It can be removed from the new road - Other area can be constructed new one
Laypeople females	- Useful area for washing - Females like the room -It can work for gathering - Good place for resting	-Renovation the structure - Reconstruct the inside -Add facilities such as lights, seats, and power - Apply high quality of materials in renovation
Laypeople Elders	- It is the identity of the area - It is an important part of history - It is part of the culture - It is full of memory for the next generation	- Keep the structure as it is - Renovation of the structure - Find engineering solution of the road - Make it visible for tourists
Laypeople youth	- It is an old structure which is no longer useful - It is so dirty and unsafe for females - It is not healthy area to use the water - Budget should allocated for sport than renovation of a useless building - It is not a symbol of the culture	- Demolish the structure - Open the road - Renovate the area - Built recreational activities than historic

The interviews had included two major groups of the respondents including the first part as the governmental bodies like the local urban manager, member of the council, Heritage supervisor officer, and politicians, and the other side laypeople included male, female, youth, and elder. The interviews took place in three different location including governor office, village council, and heritage center. Majority part of the governmental bodies believed that the heritage structure should conserve at it was without any changes, renovation, decoration, and integration, under influences of the heritage officer. However, local manager believed that the structure should renovate as a touristic asset to facilitate circulation of income for the local people.

Interview with the local people was more diverted from a unique central point of view. The interview took the position in the mosque, tomb, library, and gardens. For the elder people particularly male, the structure should keep as a heritage asset and value for the next generation to deliver the traditions and lifestyle without any intervention. However, generally they believed that the *Payab* structure has been a feminine realm than masculine, so, opinions of the females should be more important than male. For the females, the structure still was included functions to serve the female needs such as access to water, safe, and chatting area, however, it needed more renovation, decoration, and facilities such as light, ventilation, and sitting areas. Nevertheless, for the younger inhabitants, the time of the historic structure expired and no longer, this structure can work with the new system of the

water supply and sanitation; but the new road was more important than the old structure in the area. Therefore, they recommended filling the historic structure with the soil and construction wastes as the basement of the new road. All the results of the interviews summarized in table 2.

These kinds of contradictions were predicated on the circumstance of the research in the traditional context. So, for overcoming the problem, the several discussions with both governmental and laypeople arranged and finally the opinion of the heritage officer and female respondents concluded as the benchmark of the project for designing process.

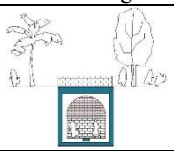
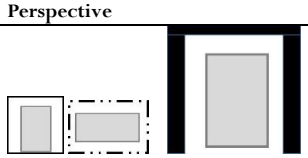
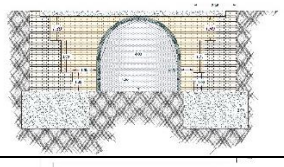
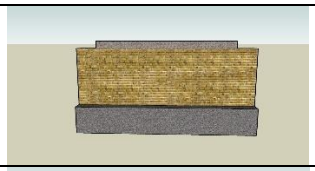
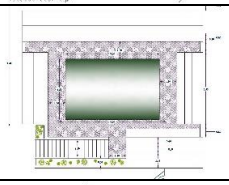
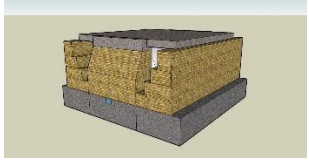
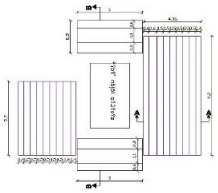
5. Findings and Derivation of a Design Solution

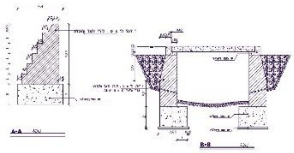
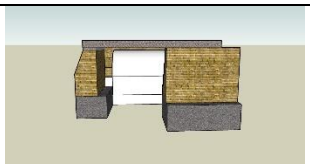
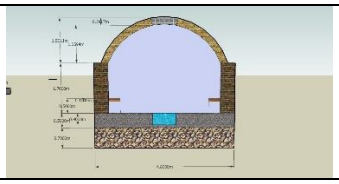
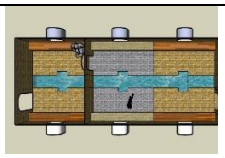
Despite the contradiction among respondents, the results identified that major tendency was to conserve the structure with rehabilitation approach, for both user and tourists to achieve the new road construction. However, this tendency was higher among elder, female and heritage office, selecting a conservation-rehabilitation approach created a consensus between government and governance in the designing process to achieve all expectations of users. Additionally, the results demonstrated that new generations were not proud of the historic structure as the symbol of the heritage and tradition and they preferred renovation and modernity. Therefore, it could be argued that the function of the structure as a public service decreased and the current role of the structure was not clear in the modern city. In this regard, all strategies of design were oriented with an integrated conservation and rehabilitation approach for solving the problem.

To achieve the task of protection of the heritage structure in the location with the ability to stand under weights of the road and those heavy machines, the solution was to conceptualize a protective shield in the surrounding like a box to keep the structure in the inside safely. The concept was to form a spatial envelopment to put the historic structure inside for conserving also to open the new road. Simultaneously, the box also should be included openness to be accessed from the outside to the inside. Therefore, this idea developed into the idea of an underground bridge in the upper side of the historic structure to protect it from upper sides and convert the weights of the roads and transports into the ground. Simultaneously, the issue of the earthquake has been crucial matter particularly with the vacation of surrounding area of the structure; the historic resistance of the historic structure dramatically decreases. To solve this issue, in discussion with the civil engineer teams, it was decided to unify the foundation of the structure with the new supportive structure to protect the structure in the new position.

To implement the repeated requests from female respondents to redesign the structure more comfortable for the users, the design strategies proposed three aspects of flooring, furnishing, and decorating. In the flooring, the surface of the structure proposed repairing with local red stones to create warmer color with harmony with the colors of those traditional bricks in the walls and roof. Those stones also applied for the benching inside with a cover of the strong local jujube woods with brown colors and wonderful patterns. The decoration of the structure limited to remover the plaster from traditional bricks and polish the surface and recovering the wall and roof with a pointing of a light white cement mortar. This pointing with the white color created visual contrast based on the figure and ground theory, so the room could be perceived wider than it was. Artificial light and sockets for power predicated. The process of the design conceptualization summarized in table 3.

Table 3 Summary of the Key Ideas of the Respondents

Design Strategies	Design Tactics	Final drawing	Perspective
Conceptualization with protective box	The box should be open is some part to be accessible by users		
Protection of the structure in static box	Using of bricks and concrete to convert the road weight into the foundation		
Monitoring the quality of the heritage structure	Creation an open ring to the surrounding of the structure for periodical visiting		
Safety of users to access to the structure	Shifting the stairs and entrance from street to the sidewalk		

Protection of the structure in agents of heavy lorry	Orientation supported structure in the orientation of the road		
Facilitate inside with small rehabilitation	flooring and benching with stone and woods for resting and opening the skylight for ventilation		

6. Discussion

Participatory design in a specific case such as historical heritage should limit to the requests and desires on the outcome and output of the action than participation in the design process. Indeed, for creating a consensus among users need to follow the process of decision making similar to Dyson, Hussain, Iversen, and Manzini, the research achieved to great result for the selection of the design approach as conservation-rehabilitation (Dyson, 2004; Hussain, 2010; Hussain, et al., 2012; Iversen & Dindler, 2014). However, the discussion some professional aspects and detail parts of design could not reach to the expected design solution. Therefore, the results of the research cannot be in the way with the recommendation of Sanders and Stappers about co-design and co-creativities (Sanders & Stappers, 2008).

Observation, site analysis, precedents analysis has been so effective for the redesigning the historic structure. In detail, observation identified what kind of the material with what quality in the surrounding area existed and these results supported methods of Neuman, Groat, and Silverman (Groat & Wang, 2002; Neuman, 2006; Silverman, 2004). In addition, visiting some different precedents of historic projects addressed to applicable techniques and material in the design process. Therefore, results supported of the idea Tavasoli, Amicoa also ICHHTO based on the contextual approach to implementing the local material and technology for conservation and rehabilitation (Tavasoli, 2000; Amicoa & Curràb, 2014; ICHHTO, 2016).

In addition, the documentation of historic elements with as-built maps was significant pre-requisition step for the design process. However, this technique has been common in the archaeology more than in the architecture, but it was an essential technique for a conservation and rehabilitation project. The technique was not only guided the research and design process but also it created a great achievement for the Heritage office for further development or reconstruction. This approach as a technique was mentioned by Groat and Wang, Bell, and Deming in other research projects with different name and process, but the outcome was so effective (Groat & Wang, 2002; Bell, 2008; Tafahomi, 2010; Deming & Swaffield, 2011).

The project resulted sufficient consensus between both governmental and governance parts to keep the structure in the same location but with enhancement the quality of the project for local users, tourists, and the heritage office. In this rehabilitation, the legibility structural of the mind of laypeople did not change with regard to comment of Liopis and colleagues based on the role of reference pointing the historic structure (Llopis, et al., 2015). Therefore, the *Payab* played not only the same role as the reference point in the area but also it could be a highlighted case for visiting both local users and tourists. The conservation of the project did not change the structure or replace the form of the area, so, these results respected to the concern of Radoslav about historic context (Radoslav, et al., 2013).

Application of local materials was the great achievement of the research not only based on the availability and sustainability but also on the cultural background of those materials for the laypeople and users. Indeed, visual and perceptual aspects connected the memory and the reality inside and outside of the historic structure. This approach emphasized the character of the place to support the historical values for inhabitants, city managers, and politicians. This approach obtained to the recommendation of ICHHTO and Heritage implemented, so, the results of the research were analogous with the approach of Brimblecombe to implement the achievement into practice (Heritage, 2005; Brimblecombe & Grossi, 2014; ICHHTO, 2016).

7. Conclusion

Conservation of the historic structure in the position could possibly enhance the environmental sustainability. In detail, the *Payab* as the historic structure in underground has play the role of the connective element between of the human need and natural resources. This structure not only provided the accessibility of inhabitant to the natural water but also it supported the flora and fauna ecosystem to access the consistent natural water resource. Therefore, a linear form of olds trees on both side of the water stream and bunch of trees at the *Payab* entrance were manmade elements those applied the natural elements in highlighting of the environmental expressions. This design strategy as the keeping active the historic structure in underground potentially will result to conserve the environment suitability in the area.

In addition, the historic structure had a significance role in the social sustainability between inhabitants particularly for a minority group of old women. In other words, this place was comfortable for the old women to discuss and spending times in a microclimate and with a high level of privacy. This

specification was unique in the area that it encourages the users to claim the improvement of the physical conditions of the historic structure. Despite the new generation of the virtual social media and other urban facilities, still the historic structure provides the opportunity of such minority group. Thus, this structure provided a place reminding the cultural background, social interaction, and the sense of place.

Furthermore, the historic structure has been part of the built environment and integrated with other architectural elements in the context. Therefore, conservation of the architectural historic element in the area supports the sustainability of the built environment. The historic structure built with the natural, local, and recyclable materials that it fitted with the context. Despite application of concert to stabilize the structure, the rest of the additional elements were provided from the local and natural materials to enhance sustainability of the built environment.

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The Effect Of Parenting Style On Adolescent's Perception Towards Road Safety

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ABSTRACT

The purview of this paper is to analyze the relationships between parenting styles and adolescent risk behaviors on the road due to the critical parental role in preventing crashes among teens. The objectives of this research are to list different parenting styles that may influence adolescent behavior, to assess the relationship between parenting styles and adolescent's perception towards road safety, to determine which parenting style that promotes a desirable street protection habits among adolescent, and to propose a framework that integrated parenting style to road safety program. Descriptive and statistical analyses are used in this paper to interpret the data taken from 298 questionnaire-respondents which the parallel between the desired parenting style and the adolescent's good perception of road safety is cast using the Pearson Correlation Coefficient. A quantitative approach is employed in processing the data taken from those selected respondents then the qualitative data is composed and operated to complete the quantitative data by giving more comprehensive knowledge over the argumentation and more description of the quantitative result. More so, the study supports the substantial influence of parenting style on adolescent development such as the adolescents who are raised in authoritative households consistently demonstrate higher protective and fewer risk behaviors than adolescents from non-authoritative families.

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1. Introduction

In the stages of life, the adolescence phase is often portrayed as the most stressful for both parents and teens. Hence, the effectiveness of parenting during these years as in any developmental stages is required through an understanding of those normative developmental changes in order to provide the healthy developmental outcomes in adolescence and help parents navigate their teens' adolescence stages smoothly. Because of the situation, studies have truly confirmed that parenting styles can be varied to enable the externalize behaviors of children (Crosswhite & Kerpelman, 2009). Likewise, the impact of parenting occurs in childhood will continue to affect the behavior into adulthood; therefore, this study will examine studies that specialize in the effect of parenting styles on adolescent's general understanding in road safety regulations. In fact, Worldwide, it is known that motorbike accident ranks are the major reason for teenage mortality and physical impairment (WHO, 2015). Those unfortunate results are included in the wider scope of teenage well – being scale due to the close relationship between the wellness of an adolescent and their behaviors; furthermore, a

study was conducted in highlighting the plans which advocated the constructive behavioral options.

Effective parenting style which presents an image of parental association is contributing as a significant element in advocating valuable teenage behaviors. The supervision that is conducted by parents entitled to a vital absolute impact of drug abuse, early reproductive interaction, misbehavior, and violence (Barnes & Farrel, 1992). In the manner that analyzers recommend that the relationship between parental supervision and the teenage result is assigned to adolescent reports instead of monitoring device or vigilance (Stattin & Kerr, 2000). In contrast, the encouragement from parents was found to do nothing in teenage behavior result (Criss, et al., 2015). Several studies noted that parental supervision was linked to the minimum rank in attitude issues (Laird, et al., 2008; Stattin & Kerr, 2000). Parental management is described by conduct done by parents in organizing the adolescents in family into a unity complete with requirements of their respective phase, assessment, punitive administrant, and an ability to discuss the problem at hand of conduct offense (Baumrind, 1991). Maximum requirements are defined as an organization and restraint. Attitudes given by parents are enclosed in the term of extension of supervision and punitive damages. Based on Baumrind's typology of parenting styles, the researchers included receptivity and imperativeness of parental figures that could cover the warmth, support, and association aspects (Maccoby & Martin, 1983). Consistent with the research, parenting styles created from four different types which might be authoritarian mother and father, authoritative dad and mom, permissive dad and mom and uninvolved mother and father can be referred to Table 1 (Zare, et al., 2014). Parents who apply authoritarian style are known to set limitations with sympathy. Slightly different, authoritative style accommodates the children with massive affection and sympathy alongside high receptivity and solid rules. Then, parents who employ permissive style tend to give sympathy and passionate encouragement with less constraint. Meanwhile, parents who are uninvolved are characterized by non – existent sympathy or passionate encouragement.

Table 1 Parenting Typologies (Zare, et al., 2014).

	High Control	**Low Control**
High Responsiveness	Authoritative	Permissive
Low Responsiveness	Authoritarian	Uninvolved

Authoritative type - identified by its high note on the pair of receptivity and imperativeness, was related to self – confidence and independent behavior on the adolescent product. Then, authoritarian type – identified by low receptivity but high imperativeness, was linked to unhappy and passive adolescent outcomes. Meanwhile, permissive type – identified by high receptivity low imperativeness, was connected to disruptive and dependent adolescent attitudes. Therefore, parents are required to acknowledge their principle and significance in intelligence or capabilities due to the impact of those on adolescents is found more desirable than authority or punishment (Collins, et al., 2014).

Accurate parenting style may be seen whilst dad and mom applied the idea and information to prepare their children to fulfill the needs of the unique lifestyle or lifestyle wherein they inhabit. However, it is possible to withdraw agreement in creating an excellent parental approach that can be applicable to the bigger part of the conditions. It may be a considerable start to comprehend which approach is competent in parenting children to fit community expectations. Parental supervision is the conduct of parents which distribute and offer perceptions on their children's location, manner, and associates (Dishion & McMahon, 1998). Parental monitoring is important since it reduces adolescent externalizing outcomes. Monitoring is one of the approaches to determine the behavior and attitude of the adolescent in daily life either at home or school. As an example, research concluded that the bigger number of parental supervision is linked to low consumption of alcohol and drug abuse (Borawski, et al., 2003), and the inflation of the stage as teenagers start sexual activities that means avoid teenagers from sexual disease (Longmore, et al., 2001). Past research (Patterson, et al., 1993) states that the supervision and discipline parents asserted in household were indicated to be immensely related to adolescent' attitude issues like drug abuse or malevolence. Additionally, those issues are represented to be dangerous in riding behaviors (Donovan, 1993). The examination conducted by (Twisk, et al., 2013) on teens' travel routines and avenue fatalities for those who have not acquired licensure finds that, in epidemiological records, the position of inexperienced teens or kids may be recognized by using a manner of a preliminary high fatality threat in line with distance traveled, followed by means of a consistent decline as enjoy grows.

Parental figures serve as sufficient prominence and behavioral example toward the adolescent manner of conduct in all aspects that specifically constructs better teenage rider attitude on the avenue. Although the real aspect parents entitled to adolescent riding has not been thoroughly examined in academic reports, the core value of parental association to adolescent riding attitudes is deserved to be a primary concern since early childhood of their children. Therefore, this paperwork is composed to explain the importance of parental association in every stage of licensure and to raise awareness of the association on teenage riders. In regard of parental management that is applied on safe riding attitudes, it might be important to emphasize that teenage riding is generally perceived as complication alliances of demeanor organization, influence of household and friendship concept, and one identity of judgment and emotional; therefore, the mixture of supportive factors in adolescent might prevent the attitude issue emerged on

this stage (Jessor, 1987). Nowadays, the impacts of their buddies in their youth's life undoubtedly become one of the most important factors. Youth's behavior carefully related to the circle of relatives' environments where the youngster's behavior is manifested, discovered, recommended and suppressed (Dishion & Patterson, 2015). Additionally, a finding from a particular study in United of States was confirmed that there was a correlation between parental fashions on adolescent behavioral outcomes which specifically the vital point that determined conduct on riding was supervision done by parental figures (Hartos, et al., 2000). Therefore, it is immensely promoted that parental figures are required to integrate their association in adolescent riding routines in order to not only educating children how to handle the vehicles properly but also raising awareness of dangerous situation in riding (Davis, et al., 2012). Consequently, adolescent has acquired the multitude abilities in managing vehicles and able to remove oneself from the number of avenue accidents.

The theoretical framework in conducting this research was built to give proper knowledge on how independent variables that elemental to participate in shaping adolescent's understanding and attitude on street protection rules. The independent variable is comprised of a determinant which is a parenting style and dependent variable which is a forthcoming promising attitude of young adults. The result is described as the preferable parental approach that can be applied to integrate street protection awareness on young adults. Additionally, the result will produce an expected good attitude by employing qualified parental approach and followed by the implementation of street protection adjustment. In ensuring street protection rules are merged on adolescent behavior, it can be identified in socio statistical outline such as excellent socio statistical outline might produce a good response on street protection supervision on young adults.

2. Methodology

The aim of this research is to appraise the potency of certain parenting style on young adult's awareness of road safety mandate. The sequences of research that employed at the domain of this study are enclosed in methodological consideration. There are four research questions that are needed to be discussed in this paper, they are: the difference of parenting styles that may influence adolescent behavior, the relationship between parenting styles and adolescent's perception of road safety, to determine which parenting style that promotes the best outcome of adolescent's road safety habit, and to create a framework that integrates a desired parenting style into the road safety program. Furthermore, the collection of primary data and secondary data are processed using certain instruments by mean of calculating the data. Hence, the broad subject of study and the research questions of this paper alongside the approaches implored to conduct this research are ruled by qualitative and quantitative methods. A quantitative approach is employed in processing the data taken from the selected respondents who answer the questionnaires. Therefore, the first and second research questions are answered using a quantitative method. Then, the qualitative data is composed and operated to complete the quantitative data by giving more comprehensive knowledge over the argumentation and more description of the quantitative result. The respondents as a representative of this research were queried to comment on the statements mentioned in the questionnaire by choosing the best fit option of their personalities and choices in a three-point Likert scale. In this study, Likert scale gives the variable test items in the questionnaire with interval scale that ranges from 'yes', 'not really', and 'no'.

ANOVA was also used in the following change to analyze the variety of parenting style in this subject matter. Evaluation of variance is a statistical technique where the variant in a set of observations is divided into sufficient components. Analysis of variance (ANOVA) is an organized group of a mathematical model that contains a statistical assumption and their affiliated ordered series of actions that are exerted in examining the contrast occurred in the sample of the study.

The outline begins with the identification of parenting style and their effects on adolescents' perception of road safety regulation. Then, this study is supported by some literature reviews that related to the discussion and based on the forms of distributed survey. The development of a survey instrument consists of the drafting questionnaire and pilot test, then, the survey is conducted on the selected respondents. After the survey is completed, the descriptive analysis and statistical analysis are also carried out. The school in Miri, Sarawak was chosen as the respondents. Only students from Miri, Sarawak were selected for this research because the approval from the Ministry of Education. Data for this study are taken from secondary school students in the range of age at 13 to 19 years old or form 2 to 6 which are included in the definition of adolescent according to the World Health Organization. This phase of lifespan is believed to be transitional of growth and development between childhood and adulthood. Thus, the age category of respondents has encompassed WHO's definition of an adolescent.

In determining this sample size on descriptive surveys, it is sufficient to attain 10 % of the population or a minimum of 20 people (Roscoe, 1995). The number of the distributed questionnaire is 298 respondents as the sample size in this study. The unit of analysis for this study is taken from secondary school students in Miri, Sarawak from various family's background. The determination to choose the sample by nonsystematic and random rules creates a chance that the sample will represent the population. This technique grants every member of the selected population to possess proportionate and independent opportunity to be selected as a part of the sample (Salkind, 2012). Here, the selection of participants is induced by chance.

A questionnaire is designed as a number of inquiries textual which the respondents favor their best fitting answers in an area closely described themselves. It is known widely as a valuable device to collect data when the researchers understand the requirements needed in the study as well as the mechanism in calculating variables of interest. In this questionnaire, there are four sections such as Section A is the Demographic Information whereby the respondents need to give information about their background, Section B is related to road safety regulations' perception among the respondents, Section C is the positive behavior, and Section D is the open-ended questions for respondents. In this study, the data collection method is taken from the questionnaire that is

answered by selected respondents who are related to this research purposes. The questionnaire that is distributed to the selected respondents is relevant for this study and collected immediately after they finished answering all the questions in the questionnaire. This is used to ensure the reliability and completion of the data.

Statistical Package for Social Science Software (SPSS) version 22.0 was used to analyze data after the entire questionnaires had been collected from the selected respondents. Then, the data were analyzed using descriptive and inferential statistic where mean, median, mode, percentage, and frequencies would be supported by an illustration of the listing tables and graphs. The descriptive method is applied to obtain material about the current condition which aims to propose the character of the situation as it appears parallel with the study and to explore the reason for certain phenomena. Furthermore, in order to create the logical and comprehensive conclusions of this study, the intention of the researcher to perceive direct information from respondents is considered. The demographic factors in this study using frequency analysis to actuate the sum percentage in frequency population of Gender, Age, Siblings, Guardian, Father Occupation, Mother Occupation, Transportation, and Parenting Style. Lastly, Pearson Correlation Coefficient Analysis is a numerical calculation based on the statistic test of the interaction of two or more variables (Zikmund, et al., 2009). The two-sided crucial is administered to evaluate an ineffective conjecture. The combined spectrums from – 1 to 1 where the value of 1 gives an excellent conclusive linear relationship, the value of – 1 delivers a distinguished negative linear relationship, and a value of 0 presents nil linear relationship (Hair, et al., 2009). Consequently, the tested variables on parenting styles toward adolescents' perception of road safety regulation can decide whether there are positive, negative, or no correlation between independent and dependent variables selected in this study.

3. Discussion

The sole fixate point of the research refers to the information generating from the questionnaire that is examined by applying the Statistical Package for the Social Sciences (SPSS) of Version 22 – Windows. For every study query that is stated inside the questionnaires in the form of a demographic element, road safety regulation belief, excellent future conduct and open-ended inquiries for respondents that observes the effect of parenting fashion on adolescents' perception of street protection regulation. 298 respondents are selected among the secondary student in Miri, Sarawak to assess the demographic distribution of respondents such as gender, age, siblings, hobbies, guardian, father's occupation, mother's occupation, transportation used to go to school and parenting styles.

For this study, respondents were given the statement of each parenting style and from that, they will select which one parenting style that is best describing their parenting style. As the result, the data obtained from the questionnaire consist of 97 respondents or 32.6 % are authoritative parenting style, 71 respondents or 23.8 % are authoritarian parenting style, 82 respondents or 27.5 % are permissive style, and 48 % respondents or 16.1 % are uninvolved parenting style (Table 2).

Table 2 Number of Respondents Based on Parenting Style

Parenting Style	High Control	Low Control
Authoritative	97	32.6
Authoritarian	71	23.8
Permissive	82	27.5
Uninvolved	48	16.1
Total	**298**	**100**

Hence, it indicates that the highest number of respondents is an authoritative parenting style and the lowest is uninvolved parenting style. The frequencies and percentages for a parenting style that influences adolescents are represented in Table 3.

Table 3 The Frequencies and Percentages for Parenting Style that Influences Adolescents

Statement	1	2	3	Mean	Std. Dev
Will you show off to your friend if you have the knowledge to operate a vehicle	38 (12.8%)	142 (47.7%)	118 (39.6%)	2.27	0.673
Do you agree that the driver does not necessarily have to own a driving license	48 (16.1%)	61 (20.5%)	189 (63.4%)	2.47	0.757

Do you not care if your parents have to be blamed for your mistake	217 (72.8%)	41 (13.8%)	40 (13.4%)	1.41	0.715
At present are you receiving adequate knowledge about road safety from your parents and their parenting guidance or from your school's educational system	213 (71.5%)	57 (19.1%)	28 (9.4%)	1.38	0.652
Is road safety something that you worry about	61 (20.5%)	50 (16.8%)	187 (62.8%)	2.4	0.808
Do you think that it is not wrong for drivers to disobey the road safety regulation should not be punished	61 (20.5%)	50 (16.8%)	187 (62.8%)	2.42	0.81
Do you agree that drivers who drivers who disobey the road safety regulation should not be punished	53 (17.8%)	93 (31.2%)	152 (51%)	2.33	0.715
Do you talk or text on the mobile phone whilst riding a car or a motorcycle	175 (58.7%)	108 (36.2%)	15 (5%)	1.46	0.757
My parents/guardian always reminds me to follow the road regulations?	217 (72.8%)	64 (21.5%)	17 (5.7%)	1.33	0.673

In this table, the majority of respondents or 72.8 % choose yes about "Do you not care if your parents have to be blamed for your mistake?" and "My parent/guardian always remind me to follow the road/regulations?". It is followed by "At present are you receiving adequate knowledge about road safety from your parents and their parenting guidance or from your schools' educational systems" (71.5 %). The respondents also choose no about "Do you agree that the driver does not necessarily have to own a driving license" (63.4 %). It is succeeding by "Is road safety something that you worry about?" and "Do you think that it is not wrong for drivers to disobey the road safety regulation should not be" (62.8 %). Then, the respondents choose not really about "Will you show off to your friend if you have the knowledge?" (47.7 %) and followed by "Do you talk or text on the mobile phone whilst riding a car or a motorcycle" (36.2 %).

The respondents indicate the various reactions toward the parenting style influencing adolescent that are shown in Table 3. The highest mean shows the respondents choose not really about "Do you agree that the driver does not necessarily have to own a driving license" (mean = 2.47, STD. Dev = 0.757). Meanwhile, the lowest mean shows the respondents choose also yes about "My parent/guardian always remind me to follow the road regulations?" (mean = 1.33, STD. Dev = 0.673). This implies that the adolescent taken as the respondents in this study are aware of the road safety regulation and the importance of having a license to ride a vehicle although under low restraint or supervision of parental figures. This is supported also by the frequency of the respondents who choose yes about "At present are you receiving adequate knowledge about road safety from your parents and their parenting guidance or from your school's educational system" (71.5 %). Furthermore, that knowledge about road safety is drawn in the good perception of an adolescent in the frequency of the respondents who choose no about "Do you agree that drivers who disobey the road safety regulation should not be punished" (51 %).

The comparison of mean based on adolescents' perception of road safety from questionnaire related to statements in Table 3 and parenting styles is presented in Table 4 where the highest mean is shown in authoritative style (mean = 1.974, STD Dev = 0.238) and the lowest is shown in uninvolved style (mean = 1.851, STD Dev = 0.289). This implies the number of respondents' parenting styles referring to the authoritative approach as the highest and followed by a permissive approach. ANOVA test analysis results indicate no differences in the frequency of parenting styles that the F (3,249) = 3.062, p = 0.028. However, the results show a significant level of 0.028 approximately less than the value of 0.05. It means that there is a crucial distinctive point between adolescents' perception of road safety based on parenting style. There are two distinctive parenting styles that can be taken as consideration to exhibit adolescent's good perception in road safety regulation, they are authoritative parenting style and permissive parenting style. Thus, parenting style(s) is an essential factor that may affect the adolescents' perception of road safety.

Table 4 Comparison of Mean Adolescents' Perception of Road Safety Based on Parenting Style

Parenting Style	N	Mean	Std. Dev.	Df	F-test
Authoritative	106	1.974	0.238		
Authoritarian	70	1.968	0.221		
Permissive	78	1.924	0.245		
Uninvolved	44	1.851	0.289		
Total	**298**			**294**	**3.062**

The frequencies and percentages for adolescent's positive future behavior are represented in Table 5. The majority of respondents choose yes about "Safety Regulation will always become my priority on the roads" (65.8 %). It is followed by "I will remind my family members and friend to follow the road safety regulation" (63.8 %). The respondents also choose not really about "Given the opportunity, I would like to involve in any road safety activities in the future" (42.3 %). It is followed by "I will always follow the rules and safety regulation" (35.6 %). It concludes that the highest mean is indicated by respondents who choose yes about "Given the opportunity, I would like to involve in any road safety activities in the future" (with a mean of 1.72, STD Dev = 0.709) and the lowest is indicated by respondents who choose also yes about "Safety Regulation will always become my priority on the roads" (with a mean of 1.39, STD Dev = 0.57). By acknowledging the result, it can be concluded that the adolescent respondents in this study exhibit good road safety habit among themselves.

Table 5 Frequencies and Percentages for Adolescent's Positive Future Behavior

Statement	1	2	3	Mean	Std. Dev
I will always follow the rules and safety road regulation	186 (62.4%)	106 (35.6%)	6 (2%)	1.4	0.53
I will remind my family members and friend to follow the road safety regulation	190 (63.8%)	90 (30.2%)	18 (6%)	1.42	0.605
Safety Regulation will always become my priority on the roads	196 (65.8%)	89 (29.9%)	13 (4.4%)	1.39	0.57
Given the opportunity, I would like to involved in any road safety activities in the future	127 (42.6%)	126 (42.3%)	45 (15.1%)	1.72	0.709

In relation to the road safety habit among adolescent and parenting style, the Pearson Correlation is taken into consideration in Table 6 where the Sig. (2-tailed) value is 0.003. Because the value is less than 0.05, we can conclude that there is a statistically significant correlation between parenting style and adolescent's positive future behavior. Furthermore, taking the result of the highest mean of parenting style in Table 4 which is an authoritative approach, it is highly suggested that authoritative approach is the best parenting style that promotes a good habit among adolescents particularly in regard of driving conduct on the road. Thus, the application of the authoritative parenting style in the household is profoundly suggested in resulting in the desired outcome of adolescent's behavior on road safety regulation and conduct.

According to descriptive analysis and statistical test that is done for answering the research questions for number one, two and three in this journal, it can be concluded that parenting style is an eminent factor in influencing adolescent's perception towards road safety regulation and adolescent's positive future behavior in road safety conduct. The desirable of parenting style that can produce a striking outcome in adolescent based on the study in this paper is an authoritative parenting style. In comparison to other styles: such as authoritarian where the firmness is given without warmth or understanding – or in other word controlling is proved in previous research that this kind of household organization hampers children development and emotional growth (Mabbe, et al., 2015). Meanwhile, the permissive style of parenting where the strictness is almost none to monitoring aspect deters child's self-restraint to follow the rules or regulations outside the house or family environment; accordingly, the road regulation is only awareness in the level of knowledge but hardly applied in practice (Berk, 2014). In wider scope than road regulation awareness and application aspect, the warmth and monitoring of parents combined with positive peer pressure in a recent study is highly affiliated with adolescent

outcomes whose self-regulation marked in highest score against the substance use (Lee, et al., 2016).

Table 6 Pearson Correlation of Parenting Style to Adolescent's Positive Future Behavior

Correlations			
		Parenting Style	**Adolescent's Positive Future Behavior**
Parenting Style	Pearson Correlation	1	.174**
	Sig. (2-tailed)		.003
	N	298	298

An authoritative parenting style is an approach of parenting guidance that is found as the most responsive and the firmest yet providing more assistance to help the children. Commonly, authoritative approach motivates parent-child discussion, delivers logical thinking in restrictions, and hastening goals. Therefore, the features of an authoritative approach must be employed in drilling young adult drivers' skills and awareness into a striking degree. This awareness is not only about how they reflect it to the outcome behavior but also the willingness to disclose the information about their whereabouts due to the open communication this family employs since the childhood phase of the adolescent. Hence, the outcome is paralleled into the result of one research of Keijsers where the combination of parental monitoring and children who openly disclose information is effective against adolescent delinquency (Keijsers, 2015).

However, in order to influence adolescents' view on road safety regulations, there are several approaches implemented by governments to reduce the number of traffic accidents. For example: enforcing stricter regulations, improving roads' safety equipment, inducing a conducive environment for vehicles' drivers, and educating the young generation about road safety awareness. Nonetheless, it is perceived that the advancement of avenues resulting in a downturn of travel hazard recognition (Lajunen, et al., 1996). Improvement of boulevards and vehicles might escalate the number of street fatalities due to the increased speed of the driver who is less careful. In fact, human failure causes 90 % of all traffic hazard (Rumar, 1985). It is moderate to presume the effects of applying psychological interventions in road traffic campaign may help to reduce the number of traffic accidents. Road Safety Campaign aims to promote society's awareness and behaviors in driving safely that have been proved to produce outstanding outcomes in developed countries. The campaign based on the study is legitimately not the first study to approach such an aspect to eliminate adolescent delinquency; likewise, previous researcher issued the suggestion of effective education and prevention program to adolescent's sexual risky behavior using supportive parenting style (Simons, et al., 2016) where is associated to the authoritative parenting style as the best result of parenting monitoring provided by this study.

In Malaysia, the mandatory participation in Graduated Driver Licensing (GDL) which is the basic obligation for parents who look after their adolescents' practice driving has been amplified. Exceptionally, there is a relationship between the number of hours which parent guides their adolescent driving performance and the decrease rate of post-licensure accidents in Malaysian young adults. The convincing result was announced by research in Australia whose young adult drivers as respondents at the age category of 17 to 24-year-old completed with 42 to 50 hours of supervised practice driving were having a lower amount of vehicles violation than those adolescents with lesser training under 42 hours. Although there is limited information about the hours of supervision that needed to be afforded by parents, in supervising the adolescent in riding routine performance, parents and instructors are proposed to uphold primary concern on street protection while accompanying adolescents in complex riding conditions such as hazard anticipation and control a conducive ambiance inside the vehicles.

Postponing novice licensure is part of the crucial defense effectiveness related to Graduated Driver Licensing programs. In fact, the crash risk raises considerably at licensure, regardless of age at licensure, the delaying of license serves to reduce exposure and crash rates for a time, providing an overall reduction in lifetime crash risk. Albeit moms and dads are informed that they can put off their adolescents' admittance in autonomous riding to the extent after the age of 18 years old, majority of young adults can attain a warrant of temporary riding authorization several months later given by the regulation. Therefore, amidst the logic related to postponing admittance to provisional license is the lack of completion in driver education, inadequately parents – supervised practice riding materials, the requirement of extended routine, security cover bill, and parents' hesitancy in letting their teenagers drive independently. Some researchers concluded that adolescents of stricter parents would be restricted in carrying young children passengers and dark-time riding was recorded smaller scale of riding hazard behavior and lesser avenue offense or accidents (Simons - Morton & Ouimet, 2006). Although Graduated Driver Licensing is equipped with the limitation on riding at dark-time or with young children passengers, it shifts the responsibility of obedience on safety riding to parents. Parents who are accounted for the immense degree of Graduated Driver Licensing participation with time restriction are obtaining a more desirable outcome than the limitation of riding companions.

The advanced tools that are derived from navy observation devices consist of measurement for quickening or slowing down

report also with vehicles movement. In fact, this technology is featured by photographic equipment that notes the rider, inhabitant movement, situation outside the vehicles and downloads these data when violation to speed is recorded. In singular preliminary test excluded focus sample that represented the vital indication whose assessment given by the electronic monitoring data to the parents and teenagers may prevent fatality events. Although a little number of parents rely on technology in helping them to improve their adolescents' driving abilities, the argumentations outed by parents who were not opting this monitoring tool trusted the adolescents and avoided intrusion on adolescents' seclusion and cost.

In the further reason for restricting the admission of usage, a parent might keep their adolescents from road hazard by giving an option to have a better vehicle that equipped with advanced safety features. Between adolescents who possess the automobile independently in mentioned research beforehand, around 35 % owned huge cars which provided the best protection features; 42 % rode tiny vehicles which commonly known to own lesser safety rank; and a quarter percentage rode SUVs, pickups, or sports vehicles that were entitled to risk safety the most. However, latest cars are introduced with more safety protection features than the older ones which are covered by 70 % of adolescents in the mentioned study riding car that issued for 6 years and 35 % for 10 years. Taking significant 'effective components' into account on road safety programs, the studies and developmental studies are reviewed in this review signify some programs.

Road Safety Education should be launched at the earliest age of children as 4 to 5 years old and be lasted through primary and secondary school as developmental trends and constraints are included in the factor. Education which is taught by experienced people and teamwork with a companion is significantly beneficial in driving school and the communication in practicing is likely contributing more to the success of this program. Teaching traffic protection is deemed to be a critical element in teaching children's skill to manage road safety and there is an affirmation from parents as the primary source of example in performing street protection for the adolescents that can be a foremost tutor at the traffic situation. As an alternative in road safety knowledge programs, skills training have been taught using experiential exercises where adolescents are motivated by finding solutions to dispatch and prevent young adult drivers by accommodating drill. This program is included in the Walking School Bus (Collins & Kearns, 2005) and Walk Safe (Hotz, et al., 2009). Traffic enforcement law can never enough to control driver behavior as traffic officers cannot be in all places at all times. Hence, parents and guides are inspired by building crucial participation for teaching adolescents on street protection that conjured in the condition they encountered in riding routine and comprehend the goals that programs attempted to accomplish.

4. Conclusion

The different parenting styles that may influence adolescent behavior based on this research either positively or negatively included authoritarian parenting style, authoritative parenting style, permissive parenting style, and uninvolved parenting style. Parents' perception of traffic, the danger of stranger, and crime safety are all related to adolescents' active transportation. Several safety concerns may be encouraging parents to restraint adolescent mobility by walking and bicycling. The parenting style that promotes the best in road safety habits among adolescent is identified as an authoritative parenting style because even though they are warm but they are firm toward their children. Likewise, the authoritative parenting style that is framed into raising children or street protection training where the warmth of parental figures coupled with controllable factors such as behavioral and psychological surely produce bidirectional outcome (Pinquart, 2017). This can be achieved through sensitization campaigns within the community and organizing a common forum where parents, adolescents, and road safety officials can interact together so as to have a common ground in road safety awareness or related regulations. In this study, there are some limitations that cast by the researcher. One of them is the time limitation in distributing and calculating the survey to identify the impact of parenting style that influences adolescents' perception towards road safety regulation. It arose when the researcher was not able to decide the duration of the task due to work commitments. Additionally, this study was conducted by the limitation of 298 students in Miri, Sarawak who partial respondents did not finish all the stages of observation and mutual effort at the time this research was held. Furthermore, this research is open to further contrasting studies as students as respondents based on their family background to draw a conclusion at the influence of parenting style on adolescents' perception towards road safety regulation. Thus, additional examinations are desired to the fulfill knowledge gap and information where the next study using the same technique, data is crucial to gain the actual result and analysis the information to assess the study which is fundamental to all related researches.

This study is available for additional discussion in the juxtaposition of the impact of parenting style on adolescents' perception towards road safety regulation. Besides, the number of samples gathered can be elevated to examine more the adolescents' perception in this study. Moreover, other relationship can be researched in order to analyze the parenting style on adolescents' perception. The approach in this study is reversed equally to questioning and investigation on the exact area and selecting sample as vital information in this study. The impacts of parenting style types on adolescent behavior are needed to be studied further. In the writer's opinion, the extended research should enclose a larger sample area and be adequate in making a comparable study for it combines a wider irregular population in interviewing respondents. The current results draw a correlation between students, teachers, and parents; however, interested parties are encouraged to follow how they ground with the applied parenting style and engaging them from the onset. In terms of inducing further studies, the following pointers can suggest according to its consequences such as dad and mom should determine the authoritative parenting style in place of authoritarian parenting style, mother and father need to give more time with their adolescents due to the fact that it may reduce the opportunity of growing juvenile delinquent, parents should be engaged persistently with children so the teenagers may be prevented from committing crimes and relating themselves to law-breaking movements.

Based on the finding in this research that is concerned about the effects of parenting on adolescents' outcomes in terms of

behavior and attitude, researchers have built family-based prevention using intervention programs for parents and teenagers in educating both of the parties in creating a harmony family. These programs are provided education both of parents and young adult drivers in elaborating capabilities that fastened household relationship. As in the example, according to findings of a study on fathers' association with their young adult children, investigators suggest the strategies emphasizing dads' roles in a parental fashion that might be equivalent to the expense of restrictions in maintaining and dynamic and strong contact towards children. Meanwhile, the separated study was highlighted more on alternative determinants in the family that keep adolescents from high-risk behaviors. Accordingly, the intervention of parental supervision on novice driving school or application on road is highly suggested based on the previous study where it was conducted to ADHD young drivers (Fabiano, et.al., 2016); thus, the researcher believes that novice who is properly functioning under parental guide will score well in self-regulation and self-awareness. The study that is pointed out in the review recommends that both parents and community can imprint adolescents' outcomes. This suggests that regulation should empower society – oriented on parents' involvement. Next law enforcement also ought to put tenacious significance on an interception and or interference knowledge specifically to the needed impacts that persuaded parental fashions on adolescents' aftermath.

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Content Validation of the User Attitudinal Component and Factors in Green Building

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ABSTRACT

The green building performance gap has been well acknowledged in building industry and one of the contributors to these issues is the behaviour of users in the building. One of the element that influences the behaviour of users is the attitude of the user towards the building environment. The consideration of the human aspects especially the user attitudinal component and factor is essential as an approach in improving the building performance. This paper aims to identify the user attitudinal component and factor from the literature and to validate the research instrument by using the content validation method. The procedure of content validity include the conceptualization and development of instrument throughout an extensive literature review and to validate the relevance of the user attitudinal component and factors to be considered in green buildings. Three user attitudinal components and seventeen factors were developed from the extensive review of the literature. Ten experts were chosen to appraise the instrument of research by using a quantitative content validation. Fifteen items were accepted as relevant to the study within the accepted range and two items were eliminated from the research instrument. The study's output allows the building industry a new insight on what user attitudinal aspect to be considered and integrated when dealing in the development of green building. The output of this study greatly benefits the building designers and managers when designing, constructing and managing green buildings.

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1. Introduction

Green buildings are hugely important in safeguarding the future of next generation due to its ability to mitigate the side effects of man-made pollutants and enhance the condition of the environment. In Malaysia, the development of green buildings is aggressive and much attention is putting in. The government has propelled its green building program and policies by presenting the green rating tools, which is Green Building Index (GBI) so as to advance and thrive the building business with green building innovations. To date, according to the GBI executive summary as of 31 July 2019, 507 buildings have certified as green and the sum is anticipated to upsurge in the coming years. As indicated in the GBI executive summary, there are 261 non-residential new construction, 195 residential new construction, 16 industrial new construction, 16 non-residential existing

building, 4 industrial building, 2 interior and 13 township GBI projects in Malaysia as for now.

Many green building performance have been reported in studies. However, the results have shown contradiction to what has expected. This can be seen from De Wilde's (2014) study reported that a substantial distinction occured between the estimated energy performance and the actual energy use during the operation of buildings. He highlighted the starting point of the performance gap are come from the design, construction and building operation phases (Menezes et al., 2012; De Wilde, 2014; Salehi et al., 2015). Salehi et al. (2015) reported the energy consumption of green building is 60 per cent greater than what has predicted. Scofield (2009, 2013) also discovered that in comparison with non-LEED buildings, LEED-certified buildings failed in saving energy use and reduced emissions of greenhouse gas. Davies and Oreszczyn (2012) showed that several Britain green buildings do not achieve the expected good quality of indoor environment. The main factor was these buildings commonly used envelope (door or window) that are high airtightness to save energy, conversely, it has risen the risk of poor indoor air quality as well as overheating problems during the transition of seasons. Lin et al. (2016) looked into the actual energy usage in 31 green buildings from China in various climate regions. The research disclosed that the energy consumption of the green buildings was considerably lower than conventional buildings when it was in Hot-Summer Cold-Winter region for building type A. There is no dissimilarity of energy consumption between green and conventional buildings in building type B in all climate regions. Moreover, the type A and B buildings in Hot-Summer Cold-Winter region are discovered 15% to 23% of average energy usage lesser than the upper limits of the Chinese standard. Similarly, in Malaysia, according to Ng (2013) and Suzaini et al (2017), Malaysian green office buildings used a large quantity of energy because of construction, poor building design, management policies and behaviour of the occupants. Research by Suzaini et al (2017) reported that Malaysian green buildings devour higher energy compared to the conventional office. The researcher further asserted that the chosen non-residential GBI-certified buildings are performed superior to the simulated or intended energy performance which is on average 111 kWh/m2 annually and it was intended devouring 150 kWh/m2 every year. Notwithstanding, due to the conventional non-GBI certified buildings has the relative contextual analysis with the GBI-certified buildings, the traditional buildings were performing superior to the GBI-rated buildings at 69 kWh/m2 every year (Suzaini et al., 2017).

The behaviour of users have reported as one of the causes of the performance gap of green buildings. This is in line with Martinaitis et al. (2015) and Schakib-Ekbatan et al. (2015) studies, claiming the user behaviour is the main contributor to the performance gap especially in energy usage. User behaviour is how an individual act with the building control systems. It is the interaction between the human and building in controlling the opening of windows and blinds, lighting, air conditioning and ventilation system (Balvedi et al., 2018) to pursuit environmental comfort (Yan and Hong, 2013). Further, according to Menezes et al. (2012); Chen et al. (2015); Martinaitis et al. (2015), the behaviour of user can enormously impact the utilisation of energy. As what has referenced by Janda (2011), 'buildings do not utilize energy, yet the human do'. The building system such as air-conditioning, electrical equipment and lighting that utilized and control by the users to deal with their comfort could subsequently cause a huge amount of energy use (Harish and Kumar, 2016).

The behvaiour of the user would not happen without a reason. It can be influenced by their attitude towards the environment of the building when they occupying in the building. According to Fabi et al (2011), attitudes impact the user's behaviour directly and indirectly. For example, when a person is allocated in the building, the features in the environment of the building such as spatial allocation, lighting, colour, indoor air quality, indoor environment, noise, thermal comfort and user control of space can have profound effects on how the users perceive the attitude in the environment because the features of the environment could influence an individual's cognitive reaction (Kolvir & Domola, 2015) and influence their behaviour in the building.

Meanwhile, previous studies have shown the building design can influence human minds, attitudes and behaviours. According to Ruskin (1989) cited in Wu et al (2015), the building design could impact the human mind, conditions their psychological and shape their behaviour (Roth, 1993). Further, Ragsdale (2011) claimed that the building elements can influence the attitudes and behaviours of the user. For instance, the ambient characteristics in an office environment shows that temperature, noise, lighting could influence the user attitude towards the environment of building and this could impact on their behaviour in attaining comfort. Besides, Adrian Laeman (1995) stated that an indiviual who are not happy with the room temperature, water quality, lighting and noise conditions in their offices are more likely to affect their concentration at work. This situation would influence their attitude towards the building and subsequently affecting their behaviour in the building. Another example could be seen from Relf (1990) claiming that the interaction with plants (building features) in the building, both passive and active can alter human attitudes, behaviours, and physiological responses.

However, considerably less research has evaluated the green buildings with respect to the attitudes, behaviour and value (O'Callaghan and Hyde, 2011). It is important to consider the user's attitude in green buildings as their behaviours response to the environment of green building is based on their perceptions and attitudes of the building. By understanding the component and factors that influence the user's attitude, the designers can know how the user think, feel and behave and this may help to improve the overall building performance. One common scenario can be seen from a relatively old study is the infamous "pink prison experiment", which concluded that the temper of the prisoners were soothed when they were placed in the pink-walled cells (Schauss, 1979). This discovery became so famous and commonly recognized that the prison cells in Canada and the USA were painted in bright pink colour as well. The colour of the prison creates a positive attitude to the inmates which

helps to soothe their mood and behave tamer. As such, the design of the green building needs to make an attempt at personalizing the attitude of the user by undertstanding how they feel, think and behave in the building. For instance, the building systems display in green building that highlight the perceived attitude of users would impact the users acting in a behaviour that increase the performance of the green building. By addressing the attitude of the individual, it will result in a change of behaviour on the use of the facility in green building.

Therefore, it is crucial to consider the attitude of the user in a green building. By identifying the user attitude component and factors to be considered, this could add a new dimension of knowledge to understand how the users' attitude can impact their behaviour and how the consideration of users' attitude could improve the green building performance. However, to date, there is still a shortage of empirical data for user attitudinal consideration in the green building where current green building developments are mostly focused on the environmental (natural resources) and economic (cost) aspects. There is still a lack of research on the social point of view where the consideration of user's attitudinal aspect in the green building could give designers a holistic point of view on what to consider about the human in the perspective of psychological when developing green buildings. Despite prior research, the balance between design and the aspect of user attitude is inadequately understood and remains vague. Moreover, given that the user behaviour can be influenced by the user attitude towards the environment of building and there are lacking of studies attempt to study what are the factors that influence the attitude of user, thus, this research aims to identify the factors that influence the attitude of user in green building and to validate the attitude factors by using content validity method.

2. Content Validity

Content validity is the degree to which elements of an assessment instrument are relevant to and representative of the targeted construct for a particular assessment purpose (Haynes et al., 1995, p. 238). A content validity assessment is needed to be conducted to validate the reliability of the new construct in research (Rubio et al., 2003). This is to ensure the research construct is related to the field of research. The construct's wording or explanation which is long or hard to understand or not applicable to the research studies may lead to lower response rates and have a tendency to produce inaccurate responses (Rubio et al., 2003). Thus, the content validation process should be conducted carefully. Many studies from various scholars such as Delgado-Rico et al., (2012), Zamanzadeh et al., (2015), Paul et al., (2016) and Vasli et al., (2018) have used content validity studies as part of the development of their research tools.

The content validy relatively begins with the development of instrument and judgment by the expert of panel (Lynn, 1986). Hence, the domain of the content linked to the phenomena of interest is first identified from a comprehensive literature review to generate the instrument items that linked to the identified content domain (Carmines and Zeller, 1979; Lynn, 1986). Eventually, a list of expert panels is chosen to judge the developed instrument (Lynn, 1986). The instruments will then be evaluated to quantify the robustness of the item in the context of the study by the selected panel of experts (Wynd et al., 2003). Usually, the evaluation process follows the process of establishing potential items to be added in the research instrument (Gilbert and Prion, 2016). This entire process will serve as the item's pre-test evaluation. Therefore, any information on the clarity and representative of the item will be produced by conducting a content validity study.

2.1 Rules of Thumbs of Conducting Content Validity

Consideration should be given to proper rules and procedures when conducting a content validity study. The instrument items are first assessed by the expert panel and the total content validity score is obtained from the Content Validity Index (CVI) score. For items that achieve a low CVI value, it indicates that the items are not useful in describing the main construct due to insufficient specifications for the construct or insufficient expertise in the judging process (Polit et al., 2007). The items deemed conceptually unreliable and therefore, will be omitted (Hinkin, 1998).

Typically, the common scale used in the content validity ratings is the 4-point scale (Lynn, 1986). Lynn stated that 3 or 5 point scales could be used. However, the most recommended scale is the 4-point scale to prevent neutral and equivocal midpoint (Lynn, 1986). Many labels were suggested for the 4-point rating scales in previous studies. The researchers indicate that the ratings of 1 and 2 are "invalid content", whereas 3 and 4 are "valid content" (Orts-Cortes et al, 2013; Parsian and Dunning, 2009; Wynd, Schmidt and Schaefer, 2003; Yaghmale, 2003; Waltz, Strickland and Lenz, 1991).

In addition, the success of the content validity study is largely dependent on the quality of the selected experts rather than their number. Selecting an appropriate list of panellists to participate in the validation process is very important because the study results are usually based on their views on the research content. The number of experts rely on the availability and willingness of experts to participate andit is usually conducted by more than seven experts (DeVon et al., 2007; and Parsian and Dunning, 2009). According to Yaghmale (2003), Five to ten experts are appropriate while Lynn (1986) advised at least three experts and said not more than ten.

The CVI has been used to quantify each item in the research instrument. There are two methods used to determine the content validity score include the score of item-level (I-CVI) and the score of scale-level (S-CVI). I-CVI refers to the content validity per item. It describes a percentage of the panel of experts with a rating of 3 or 4 as an indicator of agreement with the items. In the meantime, S-CVI refers to the entire instrument's content validity (Polit et al., 2007). The S-CVI is determined not to focus on the level score (I-CVI) of each item, but to identify the index for the content validity of the overall scale. The proportion of the agreement on the relevance of each item (I-CVI) ranges from 0 to 1 (Lynn, 1986) and the acceptable

S-CVI value is 0.8 or higher (e.g., Davis, 1992; Grant & Davis, 1997; Polit & Beck, 2004).

It is considered acceptable that the item scored more than 0.78 to 1.0 in I-CVI (Polit et al., 2007). In order to account for the expert agreement, the scores are then transformed to modified kappa value. The modified kappa value was interpreted by Landis and Koch (1977) in six categories. For example, a modest kappa value of less than 0 means no agreement, a value between 0.01 and 0.20 is slight agreement, 0.21 to 0.40 is fair agreement, 0.41 to 0.60 is moderate agreement, 0.61 to 0.80 is substantial agreement and 0.81 to 0.99 is almost perfect agreement (Viera & Garrett, 2005). In the study conducted by Banerjee, Capozzoli, McSweeney and Sinha (1999), the values above 0.75 is an excellent agreement; values between 0.40 and 0.75 are fair and good agreement; and value below 0.40 is poor agreement. However, on the basis of the latest study carried out by Orts-Cortes et al. (2013), Fleiss (1981) mentioned that the value more than or equal to ≥0.74 is considered excellent, 0.60 to 0.73 is considered good, 0.40 to 0.59 is considered moderate or weak and less than or equal to ≤0.39 is considered poor.

3. Methodology

3.2 The Process of Content Validation

The content validity for this paper was conducted in five steps (Figure 1). The development of instruments and item first develops through an extensive literature review. Questionnaires are prepared and the panel of experts review and evaluate the research instrument. A content validation analysis is performed to determine the relevance of the research instrument constructed.

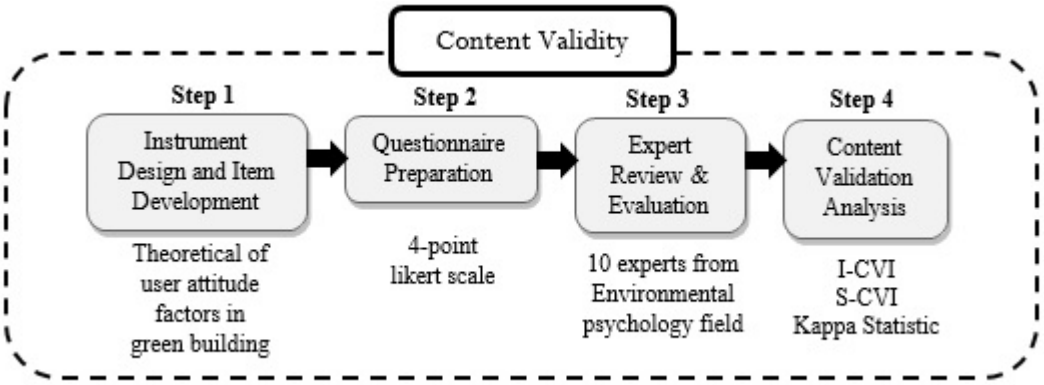

Figure 1 The process of content validation

3.2.1 Instrument Design and Item Development

The identification of the domain of content, item generation and instrument construction (Zamanzadeh et al.,2015) was done before the content validation starts. Based on the literature review, the components and user attitude factor were identified where the factors were divided into a few component categories to clearly represent the study's objective. A total of three attitude components and 17 factors were identified from the literature (refer to Table 2).

3.2.2 Questionnaire Preparation

The questionaire for the content validity was designed to validate the items obtained from the literature review, where questions were divided into a few categories to clearly represent the objective of this study. The questionaire includes of theree sections. The first sections is regarding the respondent's background. The second section is the respondent's opinion on the relevance of the user attitude factors in each components respectively. There are three components which include affective, behavioural and cognitive components where the user attitude factors are underlying in each components. The last section of the questionnaire is the respondent's comment and suggestion. This content validity questionnaire was developed using a four point Likert scale to prevent a neutral and ambivalent midpoint (Lynn, 1986). A numerical value is assigned to each level on the scale. This useually starts from 1 and increases for each level by one. The label for each point of scale used is 1= not relevant; 2= least relevant; 3= relevant; and 4= very relevant. The likert scale is only used in the second section of the questionnaire while the first and last section were open ended question.

3.2.3 Expert Review and Evaluation

The success of a Content Validity study depends largely on the quality of the selected experts rather than their number. It is very important to select a list of panelists to engage in the validity process because the study results are usually based on their views on the content of the research study. The number of experts relies on the availability of experts and their willingness to participate. The validity of the content is usually carried out by more than seven professionals (DeVon et al., 2007; and Parsian and Dunning, 2009). Yaghmale (2003) mentioned five to ten experts are appropriate. Lynn (1986) cited in Wynd,

Schmidt and Schaefer (2003) advised at least three experts and stated that ten is unnecessary.

Regarding the standards for the selection of Content Validity experts, some essential characteristics are to be considered. According to Shanteau, Weiss, Thomas and Pounds (2003), the requirements such as experience, certification, social acclamation and factual knowledge are needed to be taken into account when selecting an expert. The researcher adopted the expert requirement for this research based on the study by Skulmoski et al. (2007), namely knowledge and experience in this research area; willingness and sufficient time to engage and efficient interpersonal skills (Adler and Ziglio, 1996).

The researcher identified the number of experts in the field of environmental psychology by using judgmental sampling as the potential population for content validity. It is reasonable to use a judgmental sampling method since the experts have been selected for the perceived expertise in the subject, which they can contribute to the research area to obtain the anticipated valid result (Hatcher and Colton, 2007). Experts must be selected from stakeholders with relevant knowledge and experience in the study.

The selected experts were first contacted by electronic mail to obtain their consent to the participation in the survey. Among the experts, ten were agreed to engage in the content validation. The experts were experienced and well-performed in the field of environmental psychology and were asked to specify whether the item is relevant to the research and to mark each item from 1 to 4 with a 4 point scale range. The detail of the experts is stated in Table 1. Due to the interest of respondents, the name of the respondents is not revealed in this paper.

Table 1 Background of Experts

Panel of Expert	Contribution/ Experience
R1	An experienced environmental psychologist incorporating important psychological considerations into the design of places and objects.
R2	An environmental psychologist. Work in a wide range of environment-behaviour studies including the role of the learning environment in the educational process, environmental design within healthcare environments, predictors of pro-environmental behaviour and public participation in environmental design.
R3	Specializes in studying the reciprocal nature of well-being results from nature-based activities and achievements in extreme environments.
R4	Specialized focuses are on the structure, content, and role of psychological constructs such as human values, psychological time, self-construal and pro-environmental attitudes, and how they affect behaviour; and on a policy-based study to encourage ecological behaviours, health and well-being.
R5	Specialized in urban design and environmental psychology such as walkable environments, livable public spaces, and restorative urban places.
R6	Specialized in the interface of social, environmental, and personality psychology. Develops instruments to evaluate environmental, personality, and social constructs to incorporate these concerns into research that advance theory and enhance built and natural environments simultaneously.
R7	Specialized in social influence, persuasion, human judgment and decision-making, the psychology of risk and communication, and human-environment interactions.
R8	Specialized in cognitive neuroscience, cognitive psychology and cognitive science.

R9	Specialized in personnel psychology (Tests, Measurement and psychological assessment especially personality testing in personnel, competency and performance management) and organizational psychology (personality and organizational behavior especially in leadership, motivation and self-efficacy).
R10	Specialized in environmental psychology focusing in urban environmental performance simulation, the relationship between urban open space planning and community place attachment, and architecture and urban design.

3.2.4 Content Validation Analysis

3.2.4.1 I-CVI Computation

The experts were required to evaluate the relevance of each attitudinal factor in the Malaysian context. The scales for measuring relevancy were 1 = not relevant, 2 = least relevant, 3 = relevant and 4 = very relevant. The I-CVI is quantified based on the methods described in the study by Polit et al. (2007)). The S-CVI was computed by averaging the item-level CVIs. Many scholars have pointed out that the acceptable value for S-CVI is 0.8 above (e.g., Davis, 1992; Grant & Davis, 1997; Polit & Beck, 2004).

$$\text{I-CVI} = \frac{\text{Number of experts scoring an item with 3 and 4}}{\text{Total experts}}$$

3.2.4.2 Modified of Kappa Statistics

The modified of Kappa statistics is the proportion of remaining agreement following the removal of a chance agreement (Wynd et al., 2003). This is to make sure the collected data represent the measured variable, requiring rater reliability (McHugh, 2012). In order to increase certainty in the content validity of new instruments, Bennan (1992) recommended that both the proportion agreement (CVI) and the Kappa statistics are reported as a manifestation of data variability and as an agreement measure while considering the chance agreement (Bennan, 1992). A Kappa statistical test was conducted by inserting I-CVI into the modified Kappa statistic equation to adjust the changes to the agreement ratings by an expert panel (Polit et al., 2007). This study used the kappa value categorized by Fleiss (1981). The modified kappa value below 0.60 is classified as weak and can be considered as 'potentially problematic items' (PPI) and will be removed from the research tool. The probability of chance agreement by binomial random variable (*pc*) was calculated using the equation below. The value obtained was subsequently inserted into the next equation in to calculate the modified Kappa score (*k*):

$$pc = \frac{([N!])}{([A!](N\text{-}A)!])} \times 0.5^{N}$$

where:
N= number of experts; and
A= number of agreements rating 3 or 4

$$k = \frac{I\text{-}CVI\text{-}pc}{1\text{-}pc}$$

where:
pc= probability of chance agreement
I-CVI= content validity on item level

4. Result and Discussion

Three user attitudinal components and seventeen factors were found through a comprehensive literature review. Table 2 shows the output of the user attitudinal components and factors from the literature.

Table 2 The Output of the User Attitudinal Component and Factor

User Attitude Component	User Attitude Factors	References
Affective	Emotion and Mood	Šujanová et al. (2019); Gene-Harn et al.(2016); Totterdell & Niven (2014); Hume (2012); Küller et al (2006)
	Preference	Šujanová et al. (2019); Lee at al. (2019); Carpino et al., (2017); Gene-Harn et al. (2016); Martinaitis et al (2015); Jazizadeh et al. (2014); Gao and Keshav (2013)
	Motivation	Pereira & Ramos (2019); Delzendeh et al. (2017); Durmaz (2014); Wolfe et al. (2014)
Behavioral	Habit	Naspi et al. (2018); Hansen et al. (2018); Stazi (2017); Chang et al. (2017); Wolfe et al. (2014)
	Involvement	Valle et al. (2018); Pan et al. (2017); Lazarova-Molnar & Shaker (2016); Feng et al.(2015); Fried (2014); Gupta & Chandiwala (2010); Prindle (2010)
	Interaction	Baldi et al. (2018); Paone & Bacher (2018); Lallanne, D. (2016); Langevin et al. (2015); Thomsen et al. (2013)
	Culture	Paone & Bacher (2018); Delzendeh et al. (2017); Opoku (2015); Barzegar & Heidari (2014); Mansour & Radford (2014); Brown (2009)
	Control	Sadick & Issa (2017); Day & Gunderson (2015); Heydarian et al. (2015); Altomonte & Schiavon (2013)
Cognitive	Belief	Blay et al. (2019); Wu et al. (2017); Veitch & Gifford (1996); Eagly & Chaiken (1993)
	Perception	Durmaz (2014); Aye et al. (2005); Gou & Siu-Yu Lau (2013); Brown and Cole (2009); Monfared & Sharples (2011)
	Learning	Xiong et al. (2018); Jamaludin et al. (2017); Khalil et al. (2011)
	Persuasion	Fabi et al. (2017); Wu et al. (2017); Wolfe et al. (2014); Wu (2015); Larsen et al. (2010); Schott et al. (2012)
	Attention	Bayer et al. (2017); Lee & Wohn (2016); Wu (2015)
	Memory	Jahncke et al. (2011); Roelofsen (2008)
	Information	Fabi et al. (2017); Hauge et al. (2011); Wolfe et al. (2014); Kulatunga et al. (2006)
	Personality	Schweiker et al. (2016); Hellwig (2015); Berglund & Gidlöf (2000)
	Social norm	D'Oca et al. (2017); Mulville et al. (2017); Anderson (2015); Tetlow et al. (2012)

The content was validated by the selected experts involved in the field of environmental psychology and the content results were shown in Table 3. A majority of experts rated each factor as relevant to the study. 3 out of 17 factors (emotion and mood; preference; habit) received a high level of I-CVI scores (I-CVI= 1). Out of the 17 factors, 8 factors (motivation; control; belief; perception; social learning; information; personality; social norm) scored I-CVI of 0.9 and 4 factors (involvement; social interaction; culture) scored I-CVI 0.8. However, there are two factors (attention; memory) were reported with a low level of I-CVI 0.60, showing that this item had no significant relevance as a factor to be considered in green building. The acceptable level to be considered as high relevancy is between 0.78 and 1.0 (Polit et al., 2007). The 1.0 score denotes unanimous agreement with the items relevant to the scope of the study by all the expert panel.

Table 3 I-CVI Score

Attitudinal Component and factor	**Expert agreement**										**Total agreement**	**I-CVI**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
Affective												
Emotion and mood	/	/	/	/	/	/	/	/	/	/	10	1
Preference	/	/	/	/	/	/	/	/	/	/	10	1
Motivation	/	/	/	/	/	/	/	/	/	x	9	0.9
Behavioural												
Habit	/	/	/	/	/	/	/	/	/	/	10	1
Involvement	/	/	x	/	/	/	x	/	/	/	8	0.8
Interaction	/	/	/	/	/	/	x	/	x	/	8	0.8
Culture	/	/	/	/	/	/	x	/	x	/	8	0.8
Control	/	/	/	/	/	x	/	/	/	/	9	0.9
Cognitive												
Belief	/	/	/	/	/	/	/	/	x	/	9	0.9
Perception	/	/	x	/	/	/	/	/	/	/	9	0.9
Learning	/	/	/	/	/	/	/	/	x	/	9	0.9
Persuasion	/	/	/	x	/	x	/	/	/	/	8	0.8
Attention	/	/	x	/	/	x	x	/	x	/	6	0.6
Memory	/	/	x	x	/	x	/	/	x	/	6	0.6
Information	/	/	/	x	/	/	/	/	/	/	9	0.9
Personality	/	/	/	/	/	/	/	x	/	/	9	0.9
Social norm	/	/	/	/	/	/	/	/	x	/	9	0.9
S-CVI												0.85

Furthermore, in Table 4, the modified Kappa statistical scores were shown to demonstrate the ability of this instrument to be free from the response bias on the agreement that is likely to happen by chance. The evaluation is based on the standard recommended by Cicchetti (1984) and Fleiss (1971) as highlighted by Wynd et al. (2003). Only two factors (attention; memory) were considered weak and the rest score excellent within the acceptable range.

Table 4 Modified Kappa Statistic

Attitudinal Component and factor	Total agreement	I-CVI	P_c	k	Evaluation
Affective					
Emotion and mood	10	1	0.001	1	Excellent
Preference	10	1	0.001	1	Excellent
Motivation	9	0.9	0.010	0.899	Excellent
Behavioural					
Habit	10	1	0.001	1	Excellent
Involvement	8	0.8	0.044	0.791	Excellent
Interaction	8	0.8	0.044	0.791	Excellent
Culture	8	0.8	0.044	0.791	Excellent
Control	9	0.9	0.010	0.899	Excellent
Cognitive					
Belief	9	0.9	0.010	0.899	Excellent
Perception	9	0.9	0.010	0.899	Excellent
Learning	9	0.9	0.010	0.899	Excellent
Persuasion	8	0.8	0.044	0.791	Excellent
Attention	6	0.6	0.205	0.497	Weak
Memory	6	0.6	0.205	0.497	Weak
Information	9	0.9	0.010	0.899	Excellent
Personality	9	0.9	0.010	0.899	Excellent
Social norm	9	0.9	0.010	0.899	Excellent

Table 3 and Table 4 showed a comprehensive result regarding the relevance of the items to the attitudinal component in the I-CVI score and the modified kappa statistic score. Items with I-CVI more than 0.78 and modified Kappa value above 0.6 are retained. However, the items with low I-CVI and modified statistic kappa scores below 0.78 and 0.6 respectively were subject to deletion. Surprisingly, two attitude factors, 'Attention' and 'Memory' (categorized under cognitive component) did not appear to be the important factors to be considered in green buildings, which only accounts for 50 % of total consensus explained.

Attention is important in shaping human perception and action in built environment (Bayer et al., 2017). The basic principle of attention is a set of organize process through which a person select specific environmental stimuli or inputs for cognitive processing (Graetz, 2006). Commonly, only one input is processed consciously which called as the attended input while the unattended inputs such as the environmental stimuli (background noise, room temperature), are processed unconsciously. An unconscious monitoring can detect changes in inputs when a person is not attending consciously, however that input might be important. Then, a process called attention controller may push the information into conscious awareness and resulted a new attended input. Then, a shift in attention perceived either in controlled, selective or unexpected, causing a distraction happen.

The enchanting description of green building captures the ideas to improve the environment and create a better place for human to stay and live should not only designing the building to save energy, the consideration of how the building environment can influence the attention of users is important. Whether working or staying in green building, the users are engulfed by the environmental information (Graetz, 2006). The features in the environment draw the user's attention such as a spacious space for activity, the color of the wall, the lighting of the room or even the smell of the ambient where all these environmental information could awash the users, affect users' emotion, cognitive process and behavioral consequences. However, the attention factor do not attain a high score in the content validity assessment. This most probably due to the manipulation of visual attention is not as simple as aesthetic activity where the designers can manipulate the visual form to create designs that let the people feel harmonic, happy and satisfy. Further, Bylinskii et al., (2015) stated the progress evaluation for

attention is particularly difficult. In an attempt to understand attention, various taxonomies and other categorization such as multiple types of computational models and specific subareas of visual attention are needed.

Furthermore, buildings can tap into the user's past and experience through their senses, emotion, create a new experience for the users and memory plays a major role in helping to make this possible. Memory is a personal experience of a person on events and objects in lives. Several studies have investigated different architectural styles (Choo et al., 2017), embodiment (Vecchiato et al., 2015), contours (Vartanian et al., 2013), height and enclosure (Vartanian et al., 2015), built vs. natural environment (Roe et al., 2013; Banaei et al., 2015), lighting (Shin et al., 2014), color (Küller et al., 2009), or the impact of the built environment on human memory (Sternberg, 2010, p. 147) because the memory of an individual engage human with buildings, influencing their perception and decision making. However, memory may be less reliable and more suggestible. According to the panel of experts, it is difficult to quantify memory due to every individual has different experience with different people or situation in the past. This is in line with what has been mentioned by Guggenheim (2009) that memory is between one people to one or several objects. Memories are subjective and are only relevant and enrolled by the person. It is often faint, distanced and difficult to explain by outsiders. Giving an example, an outsider could never understand why eating ice cream can gives a person happiness if the outsider does not eat ice cream before. The actual situation of eating ice cream does not convey any link to the past situation that involved ice cream. Likewise, it is not possible to test or to question memories. The memory correlated to the ice cream is not required to hold for anybody else except the person who undergoes it. Thus, it is understood that 'Memory' factor did not reach a high consensus due to it is vague to be identified.

5. Conclusion

This study demonstrated the content validity assessment to explain the relevancy of the items through a quantitative review from the expert panels. The initial phase of the process was scale development through literature review to construct the items represented in this scale. The development of this scale is to identify the user attitudinal component and factors to be considered in green building. The items in this scale were adapt and adopt from the previous research and the content validity assessment is necessary to make sure the user attitudinal components and factors are suit to the local context. The panel of expert involved in this assessment has experience in the field of environmental psychology from oversea and local. The content validity evaluation process by the expert panel in related fields have evaluated the content and structure of the instrument by examining each of the component and factors. The process yields a good recommendation from the experts. The final construct was modified based on the quantitative results of content validity.

Given the way in which the findings of this paper can make a significant contribution to the industry, it can also be stated that the results of this paper can contribute to informed decision-making on what human aspects to be taken into account by designers and building management (by knowing what component of attitude and factors to improve the performance of green buildings). The results of this paper enable designers, building managers and building scholars to know "what aspect to consider when considering the attitude of the user. In the Malaysian context, where the element of user attitude in the design and management of green buildings is almost unheard of, the results of this paper could be of great benefit to the building industry in order to carry out the future development of green buildings. In regards to green building research on the user, most of the study does not explicitly address the validity of the instrument used to measure the user attitude in green building. Thus, this study included the validation evidence of user attitude component and factor from the previous study and suited to the local culture and practice. Quantifying the user attitude component and factors in the green building provide the opportunity to the building industry to know what is related and what to consider about the user attitude. It will also indirectly act as an educational and instructional tool for building industry to involve the user attitude when developing green buildings.

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Integration of Structures in Students' Design solutions: A tool for Assessment

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ABSTRACT

Traditional teaching practices are often questioned over their failure to generate interest and profound understanding of structures among students that further affect its integration in design solutions. Alternative teaching practices though claim to be more effective, need a sound evaluation measured through assessment of the level of integration of structures in design solutions- the ultimate objective of such courses. This paper evaluates the integration of structures in design solutions of architecture students. The integration assessment framework used for evaluation is based on building systems approach across three dimensions of performance, physicality and visual. It has been developed after comparing four prior frameworks with a 4-point scale and customized to suit the context of the academic environment. The framework offers flexibility in its use for different technical knowledge levels for each successive year of Bachelor of architecture program. The expert opinion followed by testing on design samples from all the program years further refined the framework. The study was then scaled up to include students from first to fourth years for three architecture schools that have completely different institutional environment. The findings revealed that including structural resolution in a design studio mandate may result in higher resolution of structures in design solutions but it is the building typology and student interest that may result in higher visual integration of structures in design solutions. Furthermore, the institutional environment effects can be seen in the setting of studio mandates where architecture school in technical campus laid more emphasis on resolutions of structures and services when compared to other architecture schools.

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1. Introduction

The long-standing debate over teaching methods and curriculum for structures courses (Uihlein 2013) in architectural education continue to produce new alternative teaching practices. The debate stems from the use of traditional teaching practices that may be reasons for architecture students' disinterest in structures courses (Charleson 2005) and, their difficulty in understanding structural concepts (Chiuini 2006) that further affects its integration in design solutions as well as their professional competence. Academics for long have questioned such traditional practices that are watered-down versions of engineering disciplines, for its relevance in the context of architectural education (Black & Duff 1994) and not accounting for the difference in the ways of learning by architecture students over others (Salvadori 1980). While these courses do not intentionally make another engineer out of an architect, their aim is to enable the student to utilize structures effectively in their designs through

its more profound and intuitive understanding, rather than superficial familiarity. In professional practice, such understanding may help with effective communication and coordination with engineers for better integration of structures with other building systems, which eventually can lead to architecturally, and technically sound, efficient as well as economically viable buildings.

The question, however still remains about the effectiveness of one teaching practice over the other - between the alternative or traditional practices for teaching structures courses in architecture. Since the integration of structures knowledge into design solutions is the greater objective, a deeper insight into the level of integration of structures in student design solutions would help in making informed decisions on teaching practices of structures as well as setting design studio mandates. In a review of 30 documented and observed alternative teaching practices by the author, most of them have measured their success based on student feedback and personal observations. In few cases where the assessment was made on the integration of structures in design solution but the criteria remained subjective and selective rather than holistic, even though the state of integration has been addressed in professional space through diverse approaches by the various author (Rush 1986; Bachman 2004; Charleson 2005) in past. There is, however, limited research for its understanding in Academic space (Borill 1991), where students learn structures knowledge in successive years of their program and studio mandates, as well as building typologies, affect student's design solutions that remain unbuilt and partially resolved by professional standards.

1.1 Idea of Integration

In a building systems approach, Integration is a quality of the creative process of building design whether achieved consciously or otherwise (Rush 1986) through a combination of rule systems along with logic and chance guided by creativity and intuitivism achieving harmony (Borill & Bovill 1991). It is a complex problem with no direct algorithmic solution; rather it is a play of cooperation between building systems interlinked with Architect's discernment and decision-making with the aid of both logical and intuitive minds. Architects draw inspiration from all walks of life including ideal geometries, structures, mathematical models and social archetypes (Tshumi 2005) to resolve 'ill-structured'(Jonassen 1997) or 'wicked' design problems. Specifically, Integration of Structures refers to the arrangement of the structure in conjunction with other building systems and architectural design (Salvadori & Heller 1986; Uihlein 2015). It is also a function of 'design and construction processes' that calls for the clear communication and collaboration between architects, engineers and other stakeholders, right from early design stages and, includes project sourcing, professional interactions and ideas sharing(Rush 1986). The inseparability between Structures and Architecture can be traced ancient treatise on architecture –Da Architectura, where the trio logy of Strength, Durability and Beauty form the three principles of good architecture (Morgan 1960). The increasing complexity of building due to the emergence of new typologies with the advancement in the science of material and technologies as well as sensitivity to the ecology and environment divided the 'building' profession into specialized areas such as architecture and structural engineering. Current times demand collaboration between allied professions of building industry for well-integrated and financially competitive buildings.

With energy and environment as the main concern and our increasing dependence on technology in design, Ecological concerns and Technological developments constitute Contemporary issues related to integration in building systems (Bachman 2004). Building systems, that can be classified into 4-5 types (Exterior, Interior, Services, Structures, and Site) (Bachman 2004), can integrate along three dimensions: Performance, Spatial and Visual (Rush 1986). Performance is an efficiency parameter addressing integration for space, building environment and building efficiency. Spatial integration is based on the proximity of different systems in a given space while visual integration refers to the aesthetics component achieved by the degree of exposure of any building system. The highest state of the confluence of structure and architecture is, what master builders of 20the century such as Nervi, Candela, Otto and Isler refer to as 'Structural art'. Billigton describes the structural art as the synthesis of Elegance, Efficiency and Economy (Billington 1983) – the cross cutting issues for the above said three dimension of integration. Figure 1 summarizes the concept of integration of structures in Architecture.

2. Methodology

To make an assessment framework, the authors began by comparing five different integration frameworks on their unique organizing principles, choice of parameters and scale to qualitatively or quantitatively evaluate integration for different building systems. The proposed framework internalizes the constraints of the academic environment and imparts flexibility based on knowledge levels of students from different years. It compares structural systems with 3 other building systems: exterior, interior and services on performance, physical and visual dimensions. A 4-point scale is introduced for the ease of assessments. Refinements are done after experts' inputs and testing on 11 design solutions from different years. Flexibility in usage is achieved after normalizing the services and structures knowledge and design studio mandates for 4 years of architecture program after reviewing of syllabuses of 8 architecture schools in India. This allows omitting certain parameters for lower years. Finally, taking around 30 samples of design solutions each from 1 to 4 years across 3 schools with diverse institutional setting scaled the study up. Data on Studio mandates, curriculum and studio team expertise is taken separately and compared with the assessment results for analysis. Effect of an institutional setting is also considered in the analysis.

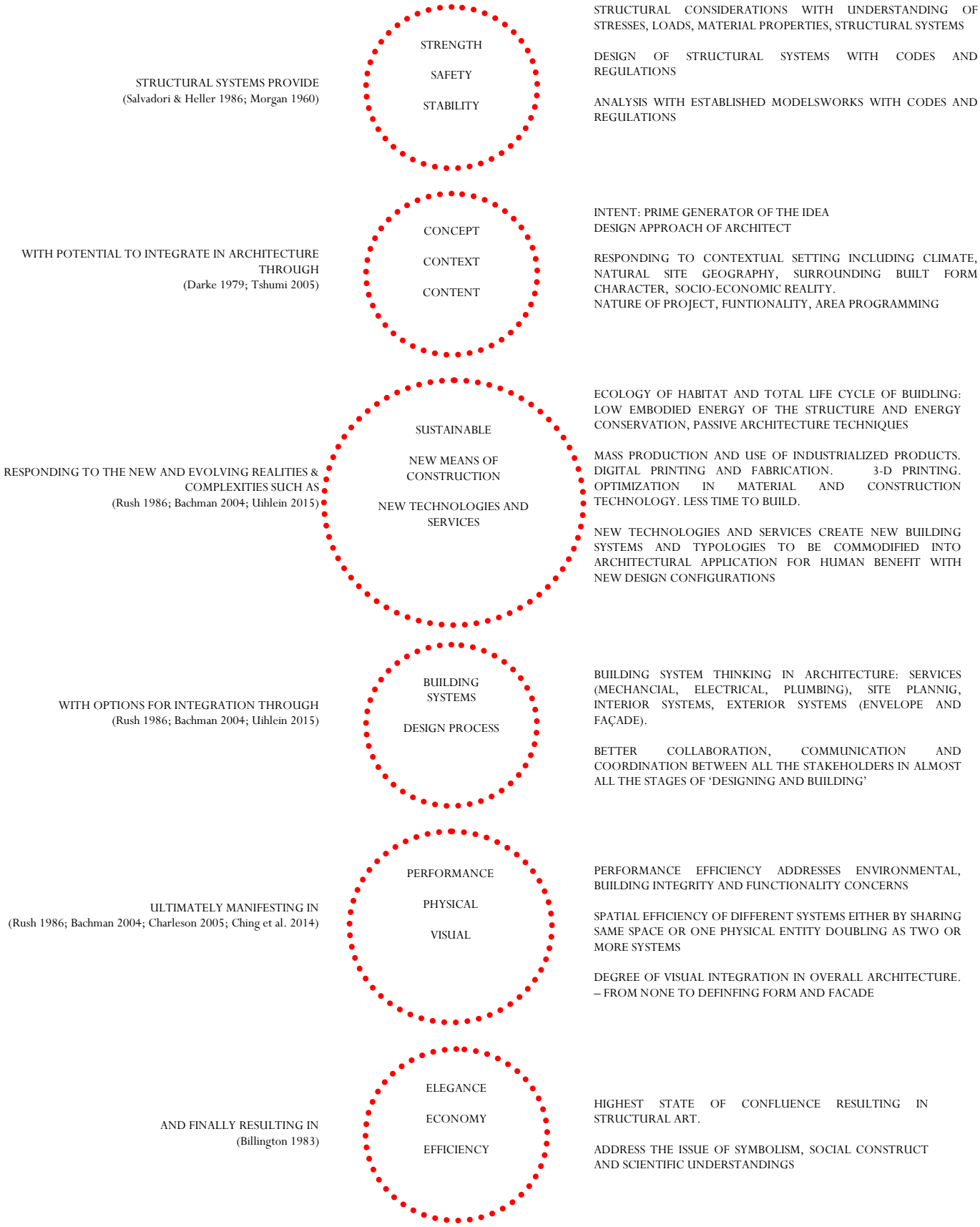

Figure 1: Understanding of Integration of Structures in Architecture (Author, 2019)

2.1 Comparing Integration Frameworks

The ultimate objective of Integration between different building systems is to achieve Elegance, Efficiency and Economy of Design, construction and Operations, in the light of contemporary challenges of Energy & environment, new technologies & services and emerging typologies by accommodating designer's intent and knowledge- all at every level of design-construction processes through collaboration. The frameworks, should, therefore, address these attributes of integration based on their unique organizing principles, choice of parameters and scale to qualitatively or quantitatively evaluate integration for different building systems and/or process of design and construction with the flexibility of considering the designer's intent and building typologies. Table 2 compares 5 frameworks (Rush, Borill, Bachman, Charleson and Ching) for their principle, parameters and building systems as well as rating systems.

2.2 Integration Assessment Framework

2.2.1 Theoretical Construct

Subjectivity inherits any assessment of buildings and its architecture since it is shaped by assessor's background, knowledge and orientation, which is further bound to change with time for the same building (Charleson 2005). However, a holistic framework can reduce the degree the subjectivity. This framework is essentially built on the lines of Rush's framework with new realities pointed out by Bachman's idea of integration. Borill's deeper understanding of constraints of the academic environment due of limited knowledge and experience of students that results in mostly conceptual and spatially resolved designs solution with little or no information on structural, services and interiors systems, is applied to reorient rush's framework for academic use. Finally, the proposed framework integrates concepts from Charleson's and Ching's framework that gives it a strong architectural focus. The framework is flexible to be applied to design solutions from all the years of architectural program and building typologies. The Proposed framework compares all the four building systems (Structures, Envelope or building exterior, building interior and mechanical or services) for three-level of integration: performance, proximity or physical and visibility or visual. The final matrix represents the interaction of the structural system with the rest of three other systems (Exterior, Interior and Services) for three dimensions of integration (Performance, Physical and Visual). Not all the building systems and sub-systems in the matrix will have indicators for different parameters and sub-parameters; only the one relevant from the perspective of the structure fill up the matrix. The same matrix is converted into a tabular form for easy use for data assessment purposes as shown in Table 3.

The ultimate objective of Integration between different building systems is to achieve Elegance, Efficiency and Economy of Design, construction and Operations, in the light of contemporary challenges of Energy & environment, new technologies & services and emerging typologies by accommodating designer's intent and knowledge- all at every level of design-construction processes through collaboration.

2.2.2 Scale

The 4 point scale is derived from Rush's Charleson and Ching's framework that defines the relationship of the structural system with other systems for the dimension of performance as either one of conflict, neutrality, active support or progenitor. For physical integration, the Rush's 5 point scale (separate, touch, connected, meshed and union) is modified to 4 points (touch and connected taken as one) for parity and for visual integration the degree of visuality along with level of modification to structural system in building exterior defines the scale (not visible, visible but modified, visible and supports architecture with much modification and primary generator of the form). Table 1 shows the summary of scales for different level of integrations.

Table 1: Scales Explanation Summarized (Author, 2019)

2.2.3 Factors affecting Flexibility of use of Framework

Scale	Rating for Performance Integration			Physical Integration	Visual Integration
	Spatial, Environmental	*Building Integrity*	*Constructability*		
1	Conflict: inhibits performance	No rationale/ Compliance with Fundamentals	Material/ construction not considered	Touching: systems are overlapping	Concealed: Structure is not exposed
2	Neutral: Does not affects performance	Basic configuration (grid/ planes, etc.) with appropriate spans in place	Contemporary material and construction ideas	Connected: systems are connected with frames, etc.	Consonance: Structure defines form but not part of exterior or interior
3	Supportive: Helps in improving performance thru sizing, configuration & detailing	Basic Member sizing & choice of appropriate system with material	Materiality and technology compliments structural system	Meshed: systems are of different material but intertwined	Synthesis/ Contrast: Structure forms part of overall aesthetics
4	Primary Generator/ Leading: actively defines and phenomenally improves the performance	Detailed structural design with calculations	Materiality and technology becomes part of construction	Unified: all building systems made of same material.	Primary Generator: Structure defines the aesthetics

In an academic environment, assuming that all the technical knowledge (Structures and services) possessed by a student at any stage of the program should be reflected and integrated into design solutions, the framework should enable to prioritize the parameters while evaluating their design solutions for integration. A review of syllabuses from 8 different schools reveals a pattern of Technical education. Table 4 and Table 5 show year wise normalized patterns for structures courses and Building Sciences courses respectively, for its ease of use in framework.

Table 2: Comparing Different Integration Frameworks (Author, 2019)

S No	Genesis and Principles	Building Systems and Sub-systems	Dimensions and Parameters	Evaluation Method	Scale
1. RUSH(1986)	The building systems in different degrees and combination of integration are evaluated for three Dimensions: Performance (6 parameters), Physical and Visible, whose mandate is defined by physiological, sociological, psychological and economic needs or design limits of its acceptability. However, Rush argues that economics plays a major role in deliberating integration through conservation of space, materials, time and Energy. Not all the performances are critical; their priority is defined by the nature of the building.	*Building Exterior* *Building Interior* *Structure* *Services* *HVAC* *Plumbing* *Electrical & Lighting* *Data & Telephone* *Vertical systems*	*Performance* Spatial Thermal Ind.Air Quality Acoustical Visual (Light) Building Integrity *Physical* *Visuality (Aesthetics/visual)*	Evaluating performance parameters by comparing them with respective standards and codes for attributes such as workspace definition, accessibility, adjacencies, air movement, temperature, humidity, comfort zones, heat transfers, air changes, air pollution, acoustics, illuminance, Equivalent sphere index, physical properties of materials, U values, thermal absorption, water and air tightness, color retention, resistance to chemicals & abrasion, bio-attack, natural & manmade disasters and, building stability	Actual measurements for technical parameters (Force, stress/strain, bending moments, Thermodynamics, Illumination, etc) in SI/FPS units. 5 point BISH Matrix with scale (Separate, Touching, connected, meshed, union) 5 degrees - no visible & no change, visible & change, visible & surface change, visible & size/shape change, visible with location/ orientation change
2. BORILL(1991)	Uses the concept of 'Game Theory ' to explain the integration based on the stakeholder's preferences and practical limitations. It is developed for educational purposes with an intention to apply it on the rough-sketch. A two-level framework involves a predesign stage for setting requirements for space, structures & environmental systems using building codes and thumb rules, followed by a conceptual design using inventory on basic quantitative information about Building codes & systems.	*Building Interior* *Structures* *Services* *HVAC* *Plumbing* *Electrical & Lighting*	*Performance* Thermal Ind.Air Quality Acoustical Visual (Light) Building Integrity	Using thumb rules, codes and 'ready to refer' data sheets to establish nature and capacity with approximate member sizing for structural systems, HVAC systems, electrical and plumbing systems. Understanding the spatial interaction of structural systems with other Services	Actual measurements for technical parameters (Force, stress/strain, bending moments, Thermodynamics, Illumination, etc.) in SI/FPS units.
3. BACHMAN(2004)	Hardware: integration among building systems; software: integration in the design process; Is an extension of Rush's framework on integration with the inclusion of post-industrial context including advancements in technologies and digression in ideologies and new typologies. 3 nonexclusive notions of integration: physical, visual, and performance, which translate into Shared space, shared image, and shared mandates.	*Building Exterior* *Building Interior* *Structures* *Services* *Site*	*Performance* Spatial Thermal Ind.Air Quality Acoustical Light Building Integrity *Visual (Aesthetics)*	Use of Location Data (Site, Normalized Climate Data), Cost Data and comparing with Building equipment and material properties data for performance in the light of design intentions for different building systems. No calculations involved.	No specific scale for analyzing performance, physical or visual integration. Uses actual measurements in SI/FPS units to refer technical parameters.
4. CHARLESON (2005)	Structures as an architectural expression of a building based on the designer's degree of subjectivity and the potential of building typology. Relating structures to attributes of building form and exterior elevation such as modulation, Depth and texture, Screening and Filtering, Structural scale, entry and, connection to building interiors. The functional response of structural systems to building a program, circulation, etc. as well as enhancing building environmental performance for parameters like light, sound, thermal conductivity, etc.	*Structure- Form* *Building Elevation* Modulation Depth & Texture Screen'g & Filter'g Structural Scale Entry *Structure- Interior* Connections Details	*Performance* Spatial Thermal Acoustical Light Building Integrity *Visual (Aesthetics)*	A Qualitative Evaluation of the different parameters and building systems based on the effect of structural systems on the architecture of the building.	Degree of exposure of structure; Three categories of the relationship between Architecture and structural form - Synthesis, Consonance, Contrast.
5. CHING (2014)	Structural planning as a function of Building design and program, codes, legal constraints, economic feasibility, systems integration, zoning laws, building height, occupancy, construction type, Fire rating and concepts of continuity & redundancy. Structural patterns as 3-D compositions of horizontal spanning, vertical support & lateral bracing systems, with attributes including Structural unit, a grid in a different scale, proportion, orientation & combination of geometries. Patterns in relation to site constraints or spatial organization.	*Building Exterior* *Building Interior* *Structural Systems* *Services*	*Performance* Spatial Building Integrity *Physical* *Visual (Aesthetics)*	Horizontal spanning and vertical supports are discussed in detail with ready-to-use or ready-to-refer data sheets to provide a basic idea of member sizes in relation to span, the arrangement of members and materiality. The lateral force resisting systems, Large span structures and MEP services are discussed conceptually.	Formal intent of structures systems in relation to architecture evolves in three ways: Exposure, concealing and celebrating.

Table 3: Matrix Converted To Table With Dimensions, Parameters And Building Systems As Well As Indicators For Integration (Author 2019 (Adapted from Rush 1986, Bachman 2004, Charleson 2005, Ching 2014))

Integration Dimension	Parameters	Sub-Parameter	Building Systems	Sub-system	Indicator
Performance	*Spatial*		**Exterior**	Form	General Structural system type and its material to determine the image, access and security
				Elevation	Structural patterns of system: unit/bay size, grid attributes
			Interior	Volume & spatial organization	Structural pattern, Module/grid for spatial planning, layout and as a space divider. Adequate Floor-to-Floor height. Sightlines. Flexibility in loading.
			Services	HVAC	Adequate ceiling height. Flexible service module. Vertical shaft efficiency. Volumetric needs. Module, volume, Number, Form, size, configuration and expansion capability of HVAC Components: Generator size; Service conduits; service terminals; compartmentalization defined for different groups based on demand.
				Electrical, Tel, data & security	
				Lighting	
				Plumbing (Water, Waste, Fire)	
				Vertical Systems	Form, module, configuration, expansion capability
	Environmental	Thermal	**Exterior**	Form	Proportions and scale of Form volume for air conditioning. Avoid thermal bridging. Horizontal plan and orientation for cross ventilation.
				Elevation	Self-shading of windows by structure. Openings for solar access and shading. Vertical stratification
			Interior	Volume & spatial organization	Adequate mass for thermal storage. Form and space support ventilation and air distribution.
			Services	HVAC	Coordination of vertical elements. Volume and form adequate for mechanical distribution. No blockage of distribution by structural elements
		Light Factor	**Exterior**	Form	Volume and form for effective daylighting
				Elevation	Appropriate sun shading with structure & other material. Reduction of contrast at openings, diffusion of light.
			Interior	Volume & spatial organization	The structure as a light reflector. Daylight distribution affected by the structural component
			Services	Lighting	Appropriate bay sizes, to provide distribution of daylight and artificial light. Space for cabling and to avoid shadows. Glare protection and shading. Flexible service module. Adequate ceiling height
		Acoustics	**Exterior**	Form	Elimination of vertical acoustical migration paths. Avoiding concentrations and flutter caused by form. Tightness against outer noise.
			Interior	Volume & spatial organization	Appropriate form/volume for sound distribution. The structure as a sound barrier.
			Services	HVAC	Structure system and material to reduce vibrations at generator and conduits
		Air Quality	**Exterior**	Form	Space for local mechanical air distribution. Leakproof structure. Elimination of vertical pollutants migration
			Interior	Volume & spatial organization	Structural height for adequate ceiling plenum space. The structure as a Barrier to outdoor and indoor pollutants.
			Services	HVAC	Volume and form adequate or air distribution. No blockage. Airtightness of S & M elements
	Building	Structure Stability	**Exterior**	Form	Form for Equilibrium and distribution of loading. Strength of connectors. Continuity and redundancy
				Elevation	Lateral bracing and preserving the architectural appearance
			Interior	Volume & spatial organization	Structure design sensitive to expansions, settlements affecting interiors.
			Services	HVAC	Loading of mechanical on structure, reduction of vibrations. Structure to ensure the performance of services in emergency situations.
	Constructability		**Exterior**	Form	Use of structural components (horizontal spanning, vertical supports, lateral bracings and membranes) for construction equipment and material support.
				Elevation	
			Interior	Volume & spatial organization	
			Services	Plumbing (Water, Waste, Fire)	Structural components double as services components (generator, conduits, terminals, control system) that further support construction/fabrication activity.
Physical			**Exterior**	Form	The structural system in its most optimized form (geometry, orientation and material) represents the varying degree of union with non-structural elements of envelope, elevation and interior. It becomes the visible defining form when unified with building exterior or interior. Structural system and its relation to elements of building exterior or interior. Integration of walls, floors, ceilings, equipment and furnishings with structural components.
				Elevation	
			Interior	Volume & spatial organization	
			Services	HVAC	Competing systems to occupy the same space. No overlapping in functions but serve technical/utilitarian function. Structural system, such as slab, columns, joists and trusses provide opportunity via voids to accommodate service conduits and terminals. Structural systems provide support for mechanical services.
				Electrical, Tel, data & security	
				Lighting	
				Plumbing (Water, Waste, Fire)	
				Vertical Systems	
Visual			**Exterior**	Form	Structural system' relationship with "defining' attributes of form & space such as ordering principles, proportioning systems, scale, articulation of corner, edges and surfaces, enclosure properties and spatial quality. Altering structure from its optimized position to suit architectural requirements.
				Elevation	
			Interior	Volume & spatial organization	
			Services	HVAC	Controlled visibility and accessibility of different components of mechanical systems for maintenance by structures. Mechanical systems and structure contributing to the aesthetics of space both internally and externally.
				Electrical, Tel, data & security	
				Lighting	
				Plumbing (Water, Waste, Fire)	
				Vertical Systems	

Table 4: Normalized Knowledge And Expectations From Structures Courses For Parameter Selection Purposes In Assessment Of Integration Of Structures In Design Solutions (Author, 2019)

Yr	Knowledge	Expectations
1	Fundamental of structures	Basic structural configuration to reflect equilibrium and stability in spans, number and location of vertical supports. Understanding of material properties is minimal.
2		Conceptual understanding of forces, loads, moments, stresses in structural members. Structural configuration starts exhibiting different grid patterns and some reference to the material with its thickness.
3	Design and analysis of structures	Member sizing with reference to the structural design of given material, choice of appropriate structural systems complimenting design requirements. Using codes and applying numerical models for the analysis of structural design for statically determinate simple buildings.
4		Conceptual understanding of statically indeterminate systems including shells, domes, vaults, etc.

Table 5: Normalized Knowledge & Expectations From Building Science & Services Courses For Parameter Selection Purposes In Assessment Of Integration Of Structures In Design Solutions (Author, 2019)

Yr	Knowledge/ subject	Expectations
1 & 2	Climatology	Passive solar architectural techniques including orientation, shading devices. Use of natural daylight and ventilation to thermal comfort advantage during different times of the year in diverse climatic zones. Heat load and U value calculations
3 & 4	Plumbing – Water and sanitation	Understanding of different water and sanitation systems in use at building, neighbourhood and city levels. Concepts of hydrology for channelling wastewater/rainwater discharge. Water requirements and design of plumbing systems. Rainwater harvesting.
	Acoustics, HVAC, Lighting, mechanical transportation systems (lifts, etc)	Acoustics as a function of form and materiality. Different acoustical requirements and control in different areas of the building. Artificial lighting and electrical wiring circuits for buildings. Concepts of lux, illumination, voltage, amperes, etc. for determining lighting requirements. Design of different kinds of HVAC or mechanical ventilation, cooling and heating systems. Thermal load calculations.Lifts, escalators, travelators design based on passenger load requirements as per codes.

Besides Structures, material understanding is also imparted through construction technology-related courses taught almost all the semesters of the program. For instance, the design of brick masonry arches, vaults, domes, and types of bonds is taught in the first and second year of the program. Design studios from the central core of the entire architecture program. They vary in scale and typology in every advancing semester. Table 6 provides project typologies and expectations for design projects in the first four years of architecture program, based on a review of syllabuses of 8 schools in India.

Table 6:: Normalized Project Types And Expectations From Architectural Design Courses For Parameter Selection Purposes In Assessment Of Integration Of Structures In Design Solutions (Author, 2019)

Yr	Projects types	Expectations
1	Personal space, café, observation decks, Childcare centres, Tod-lots, etc.	Basic understanding attributes of form and space and, its ordering principles. Use of different volumes, shapes, colour and texture in scale and proportion for a design for massing.
2	Primary schools, small resorts, house design, memorials, haat and small market place designs, Guesthouses, Religious buildings, etc.	Site planning issues, adjacencies with respect to functional requirements of the building. Response to the context. Integration with structures, Climatology and building construction.
3	High rise buildings, institutional buildings including senior schools, colleges; Hospitality buildings, Malls, etc.	Building level Environmental concerns including energy conservation, core design with services, structural systems integration. Use of passive techniques combines with energy systems for achieving thermal comfort.
4	Housing, Airports and transportation centres, hospitals and hotels design	Broader urban design issues including massing of blocks, site environmental and energy conservation issues. Use of large-span structures, the inclusion of services, resolution of functional complexity through spatial design.

(Tables 4, 5 and 6 Based on the Review of :(School of Planning and Architecture - New Delhi 2012; School of Planning and Architecture-Bhopal 2016; Indian Institute of Technology- Roorkee 2016; Ansal University 2012; University of Mumbai 2012; National Institute of Technology Raipur 2010; Anna University 2013; Council of Architecture India 2013a))

Certain Building typologies offer more integration of structural systems. For instance, large span structures such as bridges, exhibition halls, factories, etc. invariably integrate structures into their building exterior systems visually as well as spatially. This would affect the parameters selection criteria in the Assessment Framework for the evaluation of design solutions.

2.2.4 Expert Opinion and Pretesting

The author tested the framework for 11 designs solutions from 1st to 5th years. Two designs each from 1st to 4th year and 3 design representing different typologies were selected from 5th-year Thesis projects of School of Planning and Architecture-Delhi (SPA-D) and Indian Institute of Technology –Roorkee (IIT-R). Knowledge levels according to syllabuses as wells as building typologies decided relevant parameters. Assessment Method involved reviews using student's design work- models, drawings, sketches, concept notes, approach, etc. It was felt that certain

sub-parameters should be clubbed for the ease of use and availability of data.

Ten Experts included persons with expertise in pedagogy, teaching structures and design courses assessed 11 design samples from years 1 to 5 using Matrix in Table 2. The matrix was evaluated for its attributes of efficacy, efficiency, learnability, ease of use, and utility (completeness, comprehensibility, ambiguity, flexibility and usability) (Beecham et al. 2005; Siniscalco & Auriat 2005; Matook & Indulska 2009; Rittgen 2010). The Framework design was largely found to cover all the dimensions and aspects of integration with appropriate rating criteria and, suited for the academic environment. It was relatively easy to use and flexible enough to accommodate different studio projects. Experts, during discussions, further suggested a reduction in the number of data points by combining various sub-parameters for different building systems as it would be difficult to get data separately in an academic setting.

2.2.5 Pre-Testing Data Analysis

The framework was found to be flexible and can be customized as the student knowledge levels as well as information available from the student design projects data. The building sub-systems 'form and elevation' were collectively assessed for all the first and second-year designs as well as two thesis projects for evaluating their performance integration, due to lack of adequate information on building elevations since they were not resolved. Similarly, physical and visual integration was also collectively assessed for all the design sample for building exterior and interior systems, due to lack of adequate information. In the absence of any structural and material details for first and second year designs, the structure is assumed to be 9" thick load-bearing brick wall finished with plaster & paint on both sides and, 4" to 6" thick RCC slab for vertical and horizontal or inclined planes/curves surfaces, which also becomes enclosure of spaces in the initial years. Such practice is a result of instruction of studio teachers to students to use 9" thick vertical members as enclosure and, students' knowledge about brick wall sections from their construction subject in initial years. Grid frame structures and other material such as RCC, steel and brick are only seen in design solutions of 3rd and later years. Since services are not really resolved, even though they are considered for assessing 3rd and later year design solutions, the structural provision is taken into account while evaluating integration such as adequate heights and location of service generator.

The assessment results for test samples are shown in Table 7, with similar format used for other samples in full scale study. The framework showed high spatial integration for all the projects from 1st to 4th years and stadium as well as space city thesis projects, since the 'structure' of the building is 'space' enclosing elements for first and second-year projects and supports spatial layout for the 3rd year institutional and 4th year housing projects- to the extent that spaces can't be altered thereafter. This is justifiable since the projects chosen are specialized with no or little option for open space planning. The scale also showed neutral spatial integration for thesis Museum project for customizable exhibition spaces, although regular structural grid supports the spatial organization. The integration of structures with other building systems for environmental performance is primarily assessed on building volume, size and location of openings, use of the structure as thermal mass, the height of floors and space below structures to allow for the passage of services. First to fourth-year designs had adequate opening sizes placed at right positions and orientations to allow for daylighting and air and, may also affect thermal comfort depending upon the climatic situation, with a structure not interfering in the location of openings.

Table 7: Assessment Results For Evaluating Integration Of Structures In Test Samples From Different Years (Author 2019)

Integration Dimension	*Parameters*	Sub-Parameter	Building Systems		Yr 1	Yr 1	Yr 2	Yr 2	Yr 3	Yr 3	Yr 4	Yr 4	Yr 5	Yr 5	Yr 5
				Sub-system	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Performance	*Spatial*		**Exterior**	Form	3	3	3	3	2	2	3	3	2	4	4
				Elevation					3	2	2	3			4
			Interior	Volume & spatial organization	3	3	3	3	3	3	3	3	2	4	4
			Services	HVAC	NA	NA	NA	NA	2	2	2	2	2	3	
				Electrical, Tel, data & security											
				Lighting											
				Plumbing (Water, Waste, Fire)											
				Vertical Systems	NA	NA	NA	NA	3	2	2	3	2	4	2
	Environmental	Thermal	**Exterior**	Form	2	2	2	2	2	2	2	2	3	3	2
				Elevation					2	2	2	2	2	2	2
			Interior	Volume & spatial organization	2	2	2	2	2	2	2	2	2	2	2
			Services	HVAC	NA	NA	NA	NA	3	2	2	3	2	2	2
		Light Factor	**Exterior**	Form	3	2	3	3	3	2	2	2	3	3	2
				Elevation					3	3	3	3	3	2	2
			Interior	Volume & spatial organization	3	2	2	2	3	2	3	3	2	2	2

			Services	Lighting	NA	NA	NA	NA	2	2	2	2	2	2	2
		Acoustics	**Exterior**	Form	2	2	2	2	2	2	2	2	2	3	2
			Interior	Volume & spatial organization	2	2	2	2	2	2	2	2	2	2	2
			Services	HVAC	NA	NA	NA	NA	2	2	2	2	2	2	2
		Air Qty	**Exterior**	Form	2	2	2	2	2	2	2	2	2	2	2
			Interior	Volume & spatial organization					2	2	2	2	2	2	2
			Services	HVAC	NA	NA	NA	NA	3	2	2	3	3	2	2
	Building	Structure Stability	**Exterior**	Form	2	2	2	2	3	2	2	2	3	3	2
				Elevation											
			Interior	Volume & spatial organization											
			Services	HVAC	NA	NA	NA	NA	2	2	2	2	2	2	2
	Constructability		**Exterior**	Form	NA	NA	NA	NA	0	0	0	0	0	0	2
				Elevation											
			Interior	Volume & spatial organization											
			Services	Plumbing (Water, Waste, Fire)	NA	NA	NA	NA	0	0	0	0	0	0	0
Physical			**Exterior**	Form	2	2	2	3	3	2	3	3	2	3	2
				Elevation											
			Interior	Volume & spatial organization											
			Services	HVAC	NA	NA	NA	NA	3	2	2	2	4	2	2
				Electrical, Tel, data & security											
				Lighting											
				Plumbing (Water, Waste, Fire)											
				Vertical Systems											
Visual			**Exterior**	Form	3	2	2	3	3	2	2	2	2	2	2
				Elevation											
			Interior	Volume & spatial organization											
			Services	HVAC	NA	NA	NA	NA	2	2	2	2	2	2	2
				Electrical, Tel, data & security											
				Lighting											
				Plumbing (Water, Waste, Fire)											
				Vertical Systems											

In Museum design thesis project, the student had touched upon climatic issues and sought to use features such as heavy walls, light-coloured flat and insulated roofs and screened porches and patios for Delhi climate with inclined roof for north light. First and second-year projects, though do not have any material or structural details satisfying idea of stability and strength, owing to their small spans. The third and fourth-year projects show details and resolution of the structural grid and materiality. Structural calculations for basic member sizing and analysis are worked out for thesis projects from IIT-R only. Constructability could only be assessed for Space city project since it involved structural modularity for construction as a major design component.

All the projects except a third-year project and Space city thesis projects have Building interior and exterior components made of either stone cladding or plaster with paint finish over brick walls or RCC/metal structure which exhibit 'Touching' level of physical integration. In of the third year project, building skin designed for environmental comfort comprises of a set of panels clad on to the frame that is 'connected' to the main building structure. The services are not worked for both 3rd and 4th years except for the placement of lifts that are well integrated with the structure. The 'Space city' thesis project has some complexity in wall section owing to the harsh outer environment that includes insulation and frame structure. The physical integration can be marked at 'meshed' level.

Structural system does not form the part of the building aesthetics for the first four years of projects as they are covered with plaster or stone. The thesis stadium project, the structural becomes part of aesthetics and to some extent defines it as well, especially for the roof structure. In the museum project, where a student wanted to make the building as a landmark for the city, there was a good opportunity for structural systems to address form specifically the roofs of halls and auditorium.

2.3 Scaling up: Case Studies and Data Collection

This research is designed as a cross-sectional study to understand if successive build-up in technical knowledge along with the nature of design studio mandates as well as the institutional environment affects the integration of structures in design solutions.

2.3.1 Institutional Environment as Case studies Selection Criteria

Relevance of Technical subjects in architecture education programs varies with the institutional context in which program was conceived and is currently administered -For instance

Architectural schools in the west have orientations ranging from 'highly -Design discipline' oriented Beaux-Art inspired schools on one end of the spectrum to 'Engineering influenced' rationalist schools on the other end (Weatherhead 1941; Stevens 2017). Architectural education in India, though taken in diverse institutional contexts is homogeneously conceived, administered and regulated as course with a curriculum that is technically and vocationally orientated, with strong links to teaching by practitioners (Badrinarayan 2008). The Institutional context for Architectural education in India varies from 'Standalone' institutions with varying complexity of number & type of programs by institutions like Schools of Planning and Architecture (SPA), CEPT University, Sir JJ College to the ones that form of the larger Traditional University system or technical institutions like Indian Institutes of Technology (IIT), National Institutes of Technology (NIT) that are highly dominated by engineering courses. 'Private vs. Public' may contribute to another dimension of Institutional context in architectural education, at least in India, since only 1/5 of total Architecture institutions in India are government-run/aided (fully or partially) or public institutions(Council of Architecture India 2013b). Thus, three schools are chosen for the study: School of Planning and Architecture, New Delhi (SPA-D) – A standalone design institute; Sushant School of Art and Architecture, Gurgaon (SSAA) – A private School as part of larger Ansals University and; Indian Institute of Technology, Roorkee (IIT-R)- A technical University.

2.3.2 Sample Size Criteria and Data Collection

The annual intake of Architecture schools varies over ranges of 20, 30, 40, 60, 80, 100, 120 and 160 students per year (Council of Architecture India 2013b). Architectural schools with Batch sizes of 80 and above are divided into sections of 30-40 students each. IIT-R annually admits between 30-40 students and therefore has one section. SPA-D with an annual intake of 120 students has three sections of 30-40 students each per batch. SSAA admits over 160 students per year and therefore has 4 sections per year with an average strength of 39-40 per year. It becomes clear from the above explanation that student strength per section at IIT-R and SPA-D vary between 28- 37 students and would govern the sample size. Nature of studio project and its operation logistics (individual vs group) governed 'section' selection criteria in case of SSAA and IIT-R. Preference was given to more resolved design projects and ones with structures and services resolution as part of the design mandate. Projects with less than six weeks of the working time were excluded from the potential sample domain. Given the choice, Individual projects were preferred over group work for a larger sample size of design project solutions. Table 8 shows details of Samples from different institutes across different years. In the table, project mandate and studio descriptions are mentioned to understand the studio orientation and project typology.

The premise that an increase in Technical knowledge per year in the architecture program may affect its integration into design solution requires an assessment of design solutions across the years. It would also require curricular data for design and Technical subjects for each case study to understand the amount as well as the duration of dissemination of knowledge. While design processes and its solutions are influenced by designer's background knowledge and skill that shapes his/her design orientation (Wiggins 1989), they are also affected by programmatic requirements and locational contexts (Tshumi 2005) and, is reflected in his/her concept note for design solutions. In the case of academic design exercises, studio Incharge/Teacher sets the mandate for design exercises elaborating on programmatic requirements including the level of resolution, area and functionality as well as other architectural concerns.

Table 8: Data Details for Assessment(Author, 2019)

Institution and Year	Time spent on project (weeks)	Studio Project Description	Sample size	Project mandate and focus
SPA-D				
Year 1	10	A view deck for bird sanctuary at Okhla, Delhi	28	Spatial
Year 2	8	House design at Patel Nagar, Delhi	30	Spatial
Year 3	16	Institutional Building at BHU, Varanasi	30	Spatial, Structural, Environmental
Year 4	16	Chandigarh Airport	26	Spatial, Structural
Year 4	16	Slum Rehabilitation and Housing – Delhi	15	Spatial
SSAA				
Year 1	10	Pavilions	32	Spatial
Year 2	10	Gurgaon Habitat Center, Aravalli Hills	30	Spatial
Year 3	16	Architecture and Design School, Aravalli Hills	30	Spatial, Environmental
Year 4	16	Housing – Gurgaon	21	Spatial
IIT- R				
Year 2	10	Primary School- Roorkee	26	Spatial, Environmental
Year 3	6	Banquet Hall	28	Spatial, structural, Services
Year 4	10	Polar research institute, Antarctica	9	Spatial, Structural, Environmental

Data comprised of works of students' final design solutions that were presented to the jury. This included architectural drawings (plans, sections, elevations), concept notes, 3-D renderings and sketches, and, physical models. Structural grids and services drawings were also collected where they were available. The data pertaining to Design and Technical subjects in Case study schools was collected using a questionnaire instrument with information sources from syllabuses, group discussions with students and teachers with information pertaining to philosophical orientation of teacher, course organization, objectives, assessment methods and criteria, work-load, grading pattern, students' interest, Teacher's likeability, etc.

3. Discussion

Project typologies that demand closed or customized plans for their functional areas greatly affect the spatial integration of structures with other building systems. As observed, it remains high (around level 3) for almost all the projects across three institutions except for SPA-D's 4th year Airport Design project and partially for IIT-R's 3rd year Banquet Hall project where the open space plans can be created. The Environmental performance on the integration of structure with another system largely remains neutral except in cases of daylighting as a result of structural roof element as seen in case of an SSAA's third-year architecture design project. In other cases, the structural system may not interfere with the openings sizes and position, which is largely a design and technical decision but to some extent is also guided by a structural grid frame. Furthermore, in case of services for environmental comfort, the structural system integrates by allowing for adequate below beam heights in academic designs solutions. The structural integrity is limited to conceptual understanding of stability and strength for the first two years and thereafter, structural patterns and materiality are integrated into design solutions but calculations do not form part of any design solution. Member sizing is done through thumb rules and no numerical analysis is done in any sample. The constructability does not become part of any design project throughout the sample size except a mention in IIT-R's 4th-year project on Polar institute. Perhaps this requires material approach or particular project typologies such as pre-fabricated structures or modular structures for its integration.

Physical integration is mostly of 'Touched' level for all the samples except ones from SPA-D 3rd year institutional design and 4th-year Airport Design as well as IIT-R's 4th-year polar research institute. The brick wall with plaster and paint or cladding forms the outer wall and structural system with RCC slab or shell, although first two years design data do not explicitly mention the materiality or the structural system; it is only after the discussions with students and teachers that such facts are established. Some of the samples from SPA-D 3rd-year design and all of the 4th-year design solutions for Airport project show 'Connected' level of Physical integration between building exterior and structure. The external panels and framework are connected to the structure in the 3rd year institutional project while glass walls are connected to steel columns and frame in Airport projects. IIT-R 4th year polar institute show 'meshed' level of physical integration with structure occupying same space as thermal insulation and heating services along with building exterior and interior.

Project Building Typology plays a very important role in the visual integration of structures. It is evident from the fourth year project for Airport Design involved the use of large span structural systems. In Large span building typologies such as transportation centres, stadiums, bridges, hangars, industrial units, etc, structural system invariably become part of architectural aesthetics and in some cases, also lead them. More than 2/3 of design solutions (around 20) for Airport Design project showed active visual integration of structural systems into aesthetics. This is far more than average of 1 in 10 to 1 in 15 (2-3 designs per 30 samples) in all other studios different schools and years. While the Building typology played a major role in 4th year Airport design project, Teacher's interest was crucial factor in pursuing integration of structural systems, as she called for special lectures by structural engineers to talk and discuss about possibilities of different structural systems as well as provide a critical input on structures of students' design solutions.

Integration is a holistic idea that needs to be addressed through its different dimensions of Performance, physical and visual across different building systems and processes at each stage of design and construction. Academic environment, though limits the understanding of integration to building systems at a basic level can still sensitize students with various its aspect through design projects. The framework devised here for assessing design solution across the first 4 years of the B.Arch program across three different institutions reveals interesting facts that can further guide the formulation of studio projects across different years.

Perhaps in the only case, the effect of pedagogy based on the use of physical models in teaching structures was seen in SPA-D 1st-year design solutions. In addition, there was one common teacher for structures class and design studio. 6 students used structural logic to generate forms in their design using shells and cable-stayed structures, compared to an average of 1 in 10 to 1 in 15 per studio. In yet another case of third-year SPA-D studio, despite studio teacher have structures expertise, the visual integration achieved through structural complexity in grid frame structures remain to 2 design solutions. However, the resolution of structures was higher than other studios. It only shows that inclusion of structural systems, as an important requirement in design mandate and teacher's enthusiasm for structural systems integration, may not be critical for visual integration of such systems into design solutions. It finally comes down to a student's interest and building typology.

The effect of institutional environment can be observed in-studio mandates. IIT-R's studio mandates for 2nd year also focus on structural aspects, which is not the case with 2nd-year studios of SPA-D and SSAA. Similarly, the 3rd and 4th-year studio of IIT-R also require resolution of services besides structures. 3rd and 4th years of SPA-D require structural resolution while the only 4th of SSAA had a structural resolution as one of its mandates. This only reinforces the belief that architecture departments placed or initiated from the technical insitutes actively tend to focus on the technical aspects of design in their programs. For instance, IIT –R's architecture and planning deparment has been actively discussing structural issues in their second year design projects and, HVAC/other services in their third year studios - phenomenon uncommon to other two schools for their second and third studios. Rather structures becomes part of discussion in third year studios in SPA-D and SSAA, while services are only discussed in their 4th year projects.

4. Conclusion

The integration assessment framework has managed to give insights to the level and state of integration of structures in students' design solutions across the first four years in different institutional environments. This study tries to capture the essence of good teaching for technical subjects in very different environment of architectural education and, provide valuable information for Academics teaching structures and design courses to architecture students using both traditional and alternative practices. The findings revealed that including structural resolution in the design studio mandate may result in higher resolution of structures in design solutions but it is the building typology and student interest that may result in higher visual integration of structures in design solutions. Furthermore, the institutional environment effects can be seen in the setting of studio mandates where architecture school in technical campus laid more emphasis on resolutions of structures and services when compared to other architecture schools.

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Energy-Saving Potential of Daylighting in the Atria of Colleges in Najran University, Saudi Arabia

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ABSTRACT

Daylighting is recognised as an effective strategy for enhancing visual comfort and reducing energy used for electric lighting. Najran University, Saudi Arabia, has 15 colleges for males and 10 colleges for females. Each college has several atria and courtyards for introducing daylighting into the hearts of college buildings. However, the electrical lights used in the colleges atria and linked corridors keep on all the daytime. This study is an attempt to investigate the daylight illuminance level and energy-saving potential on the atria and linked corridors when it incorporates a time-scheduling lighting control system. The field measurements were performed in the College of Applied Medical Sciences. The results indicate that daylight illuminance in the atrium spaces are abundant with an average illumination level on the atrium floor varying from 300 lux to 3 600 lux, depending on the time of the day. In the clear sky climate of Najran city throughout the year, the time-scheduling control system is effective and found to contribute to approximately 43 855.2 kWh of annual energy savings in electrical-lighting consumption in the present case study scenario. The total annual energy savings from all 25 colleges at Najran University is 1 096 380 kWh/year, which results in a cost saving of approximately 93,512.86 USD. There would be additional substantial savings from other atria and courtyards in all of the college buildings throughout the campus.

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1. Introduction

Buildings with daylight help keep users physically and emotionally healthy (Aries, Aarts, & van Hoof, 2015). Using daylight as the primary light source of indoor structures is widely recognised as an important strategy to reduce building energy consumption and enhance indoor environment quality (Hua, Oswald, & Yang, 2011). In atrium buildings, there is adequate daylight contribution to the ground floor of the atrium and its adjacent spaces, thus eliminating a large portion of the need for electrical lighting. However, careful building design with daylighting can not only be an effective means in the reduction of energy consumption, but also, it is regarded as a beneficial design concept for numerous other reasons, such as outdoor connections, human health, comfort and satisfaction, particularly when carefully designing the building to be integrated with electrical lighting (Sabry, 2006). However, providing the required lighting levels for various activities in a building from daylight alone is becoming increasingly difficult, due to the limitation of building form and the increased building density. The design of the atrium should

ensure effective daylighting without increasing the heat gain into the building interior (Abdou, 1997) (Costanzo, Evola, & Marletta, 2017), particularly in a hot and dry climate.

Colleges in Najran University that located in a hot dry region of Saudi Arabia, incorporate atria for introducing daylighting to the heart of the colleges building and to the corridors surrounding the atria. Each atrium and linked corridors have different types of lights that keep on all the daytime and are switched off at midnight by Building management system (BMS). Recently, "The General Administration of Projects and Technical Affairs" of Najran University started installing On-Off light switches in the atria to control the lamps. However, the lamps are not appropriately controlled and stay lit during the day causing energy waste. To address this problem, the study aims to investigate the indoor illuminance from daylighting on a selected atrium and linked corridors (College of Applied Medical Sciences). It is also a numerical attempt to estimate the energy-saving potential when the atrium and linked corridors incorporate a time-scheduling lighting control system.

1.1 Daylight in Atrium Buildings

Daylighting can be defined as the introduction of natural light to the interior. An atrium is typically a large and multi-storeyed, glass-roofed space to introduce daylight to the interiors of large buildings where sidelight alone cannot penetrate the spaces (Mark & G. Z., 2014). However, in a hot and dry climate, the atrium or enclosed courtyard brings natural light indoors and keeps the indoors relatively cool as it is self-shading most of the day and protected from hot winds (Lechner, 2015). Moreover, the atrium increases the total area exposed to daylight by providing a large opening in the building core, and, accordingly, energy savings can be achieved (Stanley K.H. Chow, 2013). The amount of this daylighting available on the floor of the atrium depends on several factors, namely, the translucency of the atrium roof, the reflectance of the atrium walls and the geometry of the space (depth versus width) (Lechner, 2015). The recommended illumination level on the floor of the atrium was recorded in some studies as 100 lux and in IES standard as a maintained horizontal illumination of 200 lux (Hourani & Hammad, 2012).

1.2 Building Energy Consumption in Saudi Arabia

According to the Saudi Energy Efficiency Centre (SEEC, 2018), buildings are the main contributors to energy use and account for more than 50% of the total energy consumption in Saudi Arabia. According to the 2011 annual report by the Electricity & Cogeneration Regulatory Authority, consumption in Buildings Sector was approximately 80% of the total electricity generated in Saudi Arabia. Furthermore, per capita electricity consumption is also increasing rapidly in the kingdom due to numerous factors, such as population growth and increased use of energy-intensive appliances. Hence, the electricity demand in Saudi Arabia is expected to double by 2025 (Obaid & Mufti, 2008).Several studies have shown that daylight, if used as a main source of illumination inside buildings, can significantly reduce lighting and cooling loads and eventually result in savings in energy consumption (Alshaibani, 2001) (PE., 1991) (Chow, Li, Lee, & Lam, 2013) (Mahdavi, Rao, & Inangda, 2013). This electrical-lighting consumption saving can reach up to 75%–80% if the buildings use advanced daylighting technologies and have improved integration of daylighting systems (Veronica G., 2006) (Atif & Galasiu, 2003) (USGBC, 2018).

Energy-efficient lighting also includes considerations of the control of electrical lighting besides the use of daylight. Nowadays, the most common form of control is the standard wall switch that has been replaced, in many applications, with automatic control, such as occupancy sensing, daylight harvesting control or time scheduling. The use of lighting control systems, based on presence detection and the integration of electrical light with daylight, can lead to substantial energy savings. Previous studies reported that lighting control can lead to energy savings varying from 10% with a simple time scheduling to 60% with a total integrated solution (Halonen, Bhusal, & Y, 2010). These lighting controls will be used for maintaining the illuminance level of 100–200 lux on the floors of the corridors as well as atrium.

1.3 Availability of Daylight From Najran Sky

Najran is a city in southwestern Saudi Arabia, with a latitude of 17°29′30″ N and a longitude of 44°7′56″ E. Najran City has a desert climate where the average monthly temperature varies between 17 °C in winter and 45 °C in summer. Saudi Arabia is the second sunniest place on Earth (Mansour, Sawalha, & Salem, 2013), and Najran is among the cities with the highest daily solar radiation in Saudi Arabia of more than 6.9 kwh/m2/day (Zell, Gasim, Wilcox, Katamoura, & Stoffel, 2015). Table 1 shows that Najran City receives more than 3600 sunlight hours per year with an average of 10 sunny hours per day over the course of the year. The monthly sunshine hours vary on average between 357 h on April to August and 260 h on the remaining months of the year. Moreover, Table 1 presents the cloud cover of Najran City with an average peak below 20%. The CIE standard defines the Clear-sky as a sky with less than 30% of clouds covering, while a sky with more than 70% cloud cover is a Cloud-sky (IESNA, 2000). Thus, Najran city has a clear sky throughout the year.

Table 1 Average monthly sunlight hours, Global Horizontal Irradiance and cloud cover of Najran City. Authors based NU weather station and on (WWO, 2018).

Month	Jan	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct	Nov.	Dec.
Sun Hours	230	260	315	372	386	375	374	372	346	301	225	231
Global Horizontal Irradiance Wh/m2	229	268	285	294	317	322	295	300	294	285	246	222
Cloud cover %	1	16	10	5	3	2	17	15	1	0	2	1
CIE Overcast range %	≥ 80											

Daylight in a clear and sunny sky condition is a challenge where direct sunlight on a clear day can generate illuminance levels of up to 100 000 lux at midday (Frank, Doug, Jeff, & Josh, 2014). Daylighting in such climate is associated with negative factors, such as glare and increased cooling loads. The challenge is to control daylight in a way that light is utilised without glare and the heat is kept out (YILMAZ, 2016). Moreover, the sky condition of Najran City is clear and sunny throughout the year, which renders investigating the daylight factor associated with the worst sky condition of the overcast sky difficult. Thus, the daylight illuminance under the clear sky of Najran city will be measured and discussed in this study.

2. Methodology

This study adopts a case study method to investigate the daylight illuminance level in atria and linked corridors in the College of Applied Medical Sciences at Najran University, under the hot arid climate of Najran City. A daylight illuminance of a selected atrium was measured on different days of the year. Lighting fittings were monitored and calculation was conducted to report the energy saving from a daylight harvesting.

2.1 Description of the Case Study

Buildings of colleges at Najran University were designed with a skylight and enclosed atria to harvest daylight, enhance visual comfort and to reduce the electricity consumption by electrical lightings. The atrium of the College of Applied Medical Sciences at Najran University in Najran City (with a latitude of 17°29′30″ N and a longitude of 44°7′56″ E) was investigated. The atrium is an enclosed type that has a square shape with a daylight source and view from the triple glazing skylight and an entrance at the ground floor. The lower part of the atrium from the G/F consists of corridors and the entrance to auditoriums. The upper part, between the 1/F and 2/F, contains corridors, lecture halls and offices.

The College of Applied Medical Sciences (Figure 1) is a three-storey building with exterior dimensions of 202 m x 132 m. The building has two atria, namely, the first at the entrance for the administrators and the second at the entrance for the students. The investigated atrium is the entrance of the students with a space that is primarily used for circulation to different locations within the building. The monitored atrium and corridors are highlighted by the shaded regions. Corridors surrounding the atrium are connected to the auditoriums, lectures halls and lecturers' offices. The atrium has a maximum height of 20 m, extending from the ground floor to the roof level of the atrium. The ground floor area of the atrium is 400 m2 and the total floor area of the surrounding walkways is 200 m2. Figure 2 show the interior views of the investigated atrium. The roof is green tinted and triple glazed with an area of approximately 100% of the total projected atrium roof area. The three layers of glass in triple glazing are 6 mm green-tinted glass, and the remaining two are clear glass, from outside to inside. The exterior glass panel (green-tinted) of a triple-glazing roof has a manufacturer-stated visible transmittance of 6%, and its measured average net visible transmittance is approximately 3% under clear sky. Daylight also enters the atrium space from a northeast glazing wall of the ground floor, which is the entrance of the students.

The atrium space has a total of 16 lamps, 400 W each, halogen lamp hanging fixtures that are uniformly distributed on the atrium spaceframe to supplement lighting to the atrium floor. The lighting system also includes a total of 56 lamps, 52 W for each, recessed compact fluorescent fixtures uniformly distributed along the walkways surrounding the atrium space at all levels.

2.2 Field Measurements

The daylighting of the atrium space was monitored at different times of the year, on 18 January 2018 (different times of the day) to represent wintertime with a minimum global horizontal irradiance of 229 Wh/m2, and 25 June 2018 at midday to represent summer and days with a highest value of global horizontal irradiance of 322 Wh/m2. An initial measurement was conducted on 21 September 2017 where daytime and night-time are of approximately equal as well as the academic year starts. In hot sunny regions, such as Najran city, measuring daylight illuminance on a sunny day is sufficient because the sky condition throughout the year is almost sunny and clear sky.

As the designer considers the availability of daylighting firstly for the lowest floor (Grondzik & Kwok, 2015), the horizontal indoor illuminance measurements were collected on the atrium floor, under clear conditions to address the daylighting contribution to the atrium space. A total of 70 test points at the atrium floor area with grid space of 2.0 × 2.5 m were monitored on the horizontal work-plane, at floor height of 0.2m. The measurements were taken over an hour duration, starting at 10:00 a.m. and ending at 11:00 a.m. Moreover, 20 test points were monitored in the corridors linked to the atrium with no electrical lighting as well.

Measurements were also collected at night-time (9:00 pm.) for confirming the electrical lighting distribution at night. The outer test point was performed outdoor, away from the atrium. The collected data samples have been recorded using an AMPROBE LM-100 light meter with a basic accuracy of ±5%.

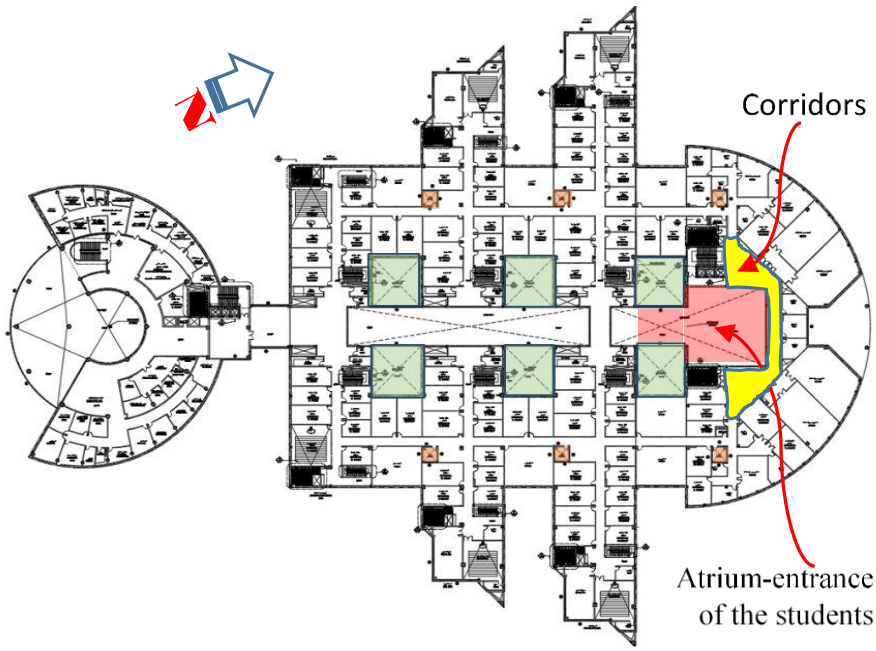

Figure 1. Plan of the College of Applied Medical Sciences, shows the investigated atrium.

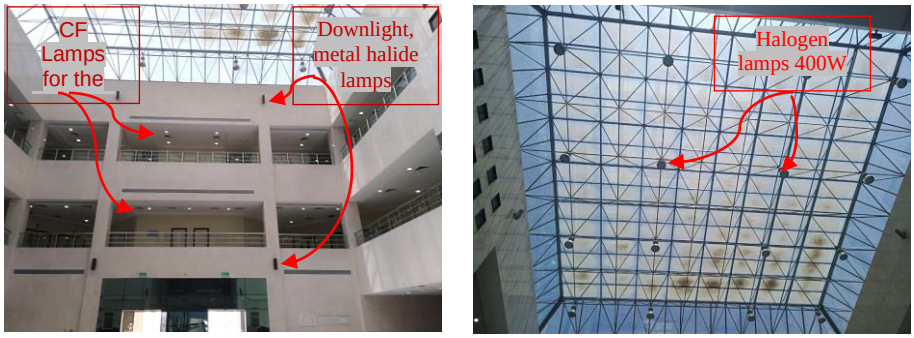

Figure 2. Interior views of the investigated atrium (Authors).

3. Results and discussion

3.1 Daylight Contribution To The Atrium Spaces

As Najran City has a clear sky condition over the year, daylight is considered a sustainable source of light. The supply of daylight is typically during the day hours with peak occupancy and electrical energy loads. Usually, daylight can sufficiently meet the demand for lighting the building during working hours. According to the American IES Standards, atrium and circulation space have work-plane illumination requirements ranging from 50 lux to 200 lux (Kim & Kim, 2010).

Figures 3 and 4, show the daylight contribution to the atrium and its distribution on the atrium floor that has been measured on 18 January 2018 at 10am. The measured points, (Fig.3), have been recorded on the horizontal work-plane, at floor height of 0.2m of the investigated atrium with grid space of 2.0 × 2.5 m. The plotted contour lines (Fig.4), shows that the daylight illuminance on the atrium floor were very high and vary from one point to the other (600lux to 2500lux). This variation is due to the exposure of some measured points to the direct solar radiation, whereas the others were shielded by dust collected on the glazed roof of the atrium.

Figure 5 shows the average daylight illuminance in the atrium and surrounding corridors spaces at different times of the day. The measurements took place on18 January 2018. Several

points on the atrium floor were measured at 7 a.m., 10 a.m., 2 p.m. and 5 p.m. The Figure shows that the average indoor daylight illuminance on the atrium floor was 1 078 lux, 1 290 lux, 3 600 lux and 281 lux respectively. The outdoor illuminance was 8 980 lux, 80 000 lux, 110 000 lux and 2594 lux respectively as well. These daylight illuminance values throughout the daytime remained sufficient for atrium activities compared to the recommended illuminance of (100 – 200) lux. However, the high lux value at 2p.m. is due to direct illumination from the sun where the atrium glazed-roof exposed to high value of outdoor illuminance of 110 000 lux. Figure 5, also, shows the daylight illuminance on the floor of the measured corridors of the first and second levels. The daylight illuminance level appeared almost the same. Table 2 summarizes the daylight illuminance at the atrium and linked-corridors that were found exceeding the requirements of atrium and circulation spaces by 10–20 times particularly at 10a.m. and 2p.m. Table 2, also, illustrates Measurements that were done during the night time for confirming the electrical lighting distribution in the investigated spaces at 9:00 p.m. The illuminance level varied between 140 lux on the atrium floor and 100 lux on the floors of the surrounding corridors, which is an acceptable light level for the circulation areas.

Moreover, the measurement was conducted at the atrium floor during summer time; on 25 July 2018 at midday, the peak illuminance rate was found to be almost 30 000 lux (when outdoor was 110 Klux), which is a high-level illumination. In accordance with the previous studies based on the occupant behaviour under daylight conditions (Mardaljevic & Nabil, 2006), the range of 100–2000 lux is the limit of useful daylight illuminance. However, the daylight illuminance values at the studied atrium spaces were found exceeding the useful range with a lux rate greater than 2000 lux in most of the atrium floor area.

In this context, it is important to report that in the hot-arid climate of "Rub' al Khali Desert" of Saudi Arabia, such as Najran City, the exposure of the atrium glass roof to direct solar radiation is creating the risk of glare as well as overheating. Thus, a dynamic solar shading system on the atrium-glazing roof is advisable to provide glare and heat protection. This issue, however, is beyond the scope of this study and could be covered by the future studies.

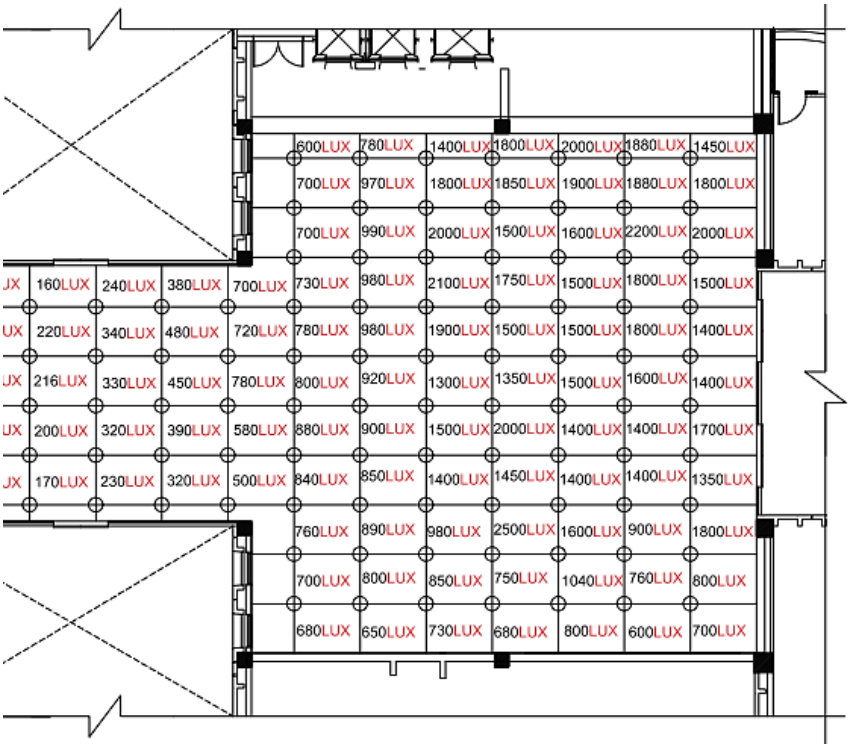

Figure 3. Illuminance level on the test points at the atrium floor area, at 10:00 a.m.

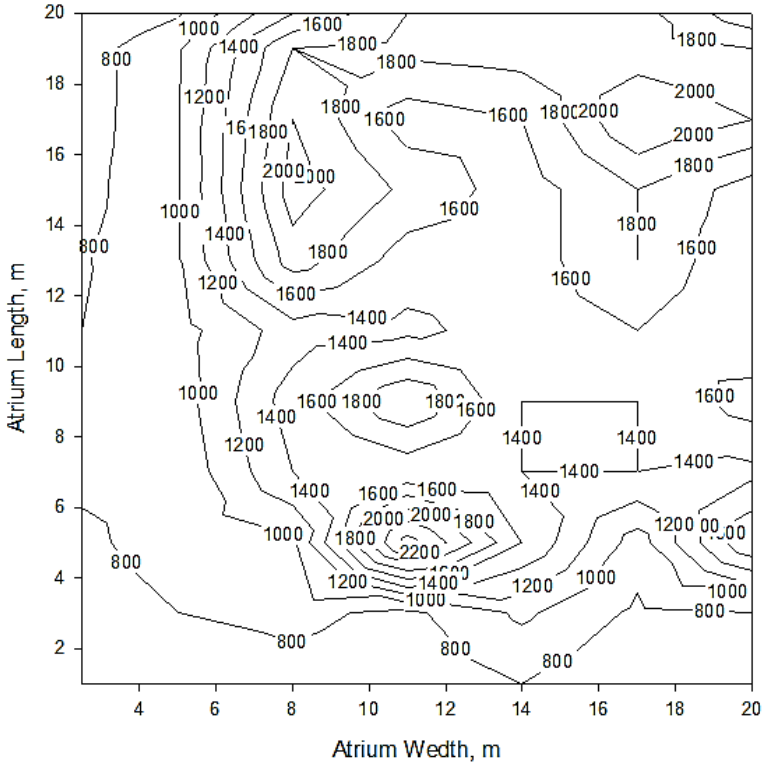

Figure 4. The contour lines of daylight illuminance level on the investigated atrium floor.

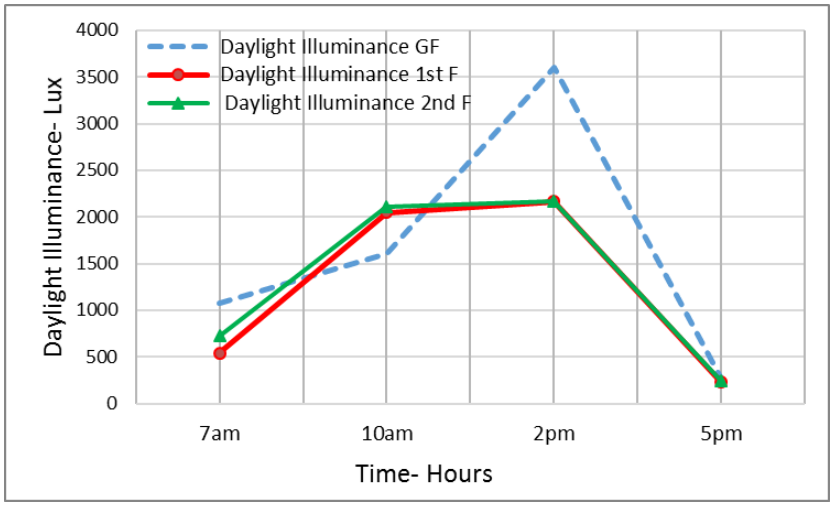

Figure 5. Daylight Illuminance distribution on the atrium floor and linked corridors at different times of the day.

Table 2. Average daylight Illuminance at different time of the day, 18 January 2018.

Time	Daylight Illuminance GF, Lux	Daylight Illuminance 1st F, Lux	Daylight Illuminance 2nd F, Lux	Outdoor Lux	Remarks
7am	1 078	543	731	8 980	On 18 January 2018: Sun Rise Time (6:37) Sun Set Time (5:50)
10am	1 610	2 050	2 110	80 000	
2pm	3 600	2 166	2 164	110 000	
5pm	281	236	245	2 594	

3.2 Lighting Energy Savings Estimation

Interior daylight by the use of daylighting reduces the level of electrical lighting and it offers a substantial energy savings. The key to designing an integrated lighting system is the electrical lighting control system. An automatic control system of time scheduling is a suitable system in such a sky condition of Najran City, for switching off selected groups of luminaires from 6:00 a.m. to 6:00 p.m.

However, Electricity consumption for the Halogen, Metal-halide and CF light fittings in the atrium and linked-corridors located at first and second floor under the automatic Time schedule /on-off controls were calculated and summarised in Table 3. The table summarises the yearly energy savings in the atrium and linked-corridors at the College of Applied Medical Sciences, Najran University.

As energy consumption by the electrical lighting equals:

$$E=P \times t \quad (1)$$

Where E represents total energy consumption of the lamps, P lamps output power (W) and t running time (h), (A. C. Menezes, 2014).

Thus, the energy saving from the daylight at the atrium during daytime (12) hours for 30 days for 12 months is equal to 43855.2 kWh/year; this value is equivalent to 43.855 Mwh per year.

3.3 Energy performance of Atria Throughout Najran University

As mentioned earlier, the two campuses of Najran University have 25 colleges for males and females. Each college has two atria introducing daylighting to the heart of the college building and to the corridors surrounding the atria. The annual energy savings from one atrium of these almost identical colleges in Najran University is 43,855.2 kWh/year. This value of energy saving is encouraging if applied to all of the 25 colleges of the university. However, by considering only the atrium of the entrance of the students, the total annual energy saving from all colleges in Najran University is (43,855.2 kWh/year x 25 = 1,096,380 kWh/year). Therefore, Table 4 summarises the energy and cost saving from the investigated atrium and 25 similar atria throughout Najran University. The time-schedule lighting control system has been proved in this study to be retrofitted in the BMS of Najran University to switch off lightings in the atria and linked-corridors spaces from 6am to 6pm for energy and cost saving.

Table 3. Energy saving records at the entrance and corridors at Najran University.

Space	Daylight system	Type of lamp	No. of lamps	Wattage	Total KW	Proposed Control system	Energy saving/day (kWh/day)	Annual energy saving (kWh/y)
Atrium space	Skylight atrium glazed roof	Halogen	16	400 W	6.400	Time schedule off: 6:00 a.m.– 6:00 p.m.	76.8	27648
		Metal halide	12	70 W	0.840	Time schedule off: 6:00 a.m.– 6:00 p.m.	10.08	3628.8
Corridors 1st F	Skylight atrium glazed roof	CF lamp	28	52 w	1.456	Time schedule off: 6:00 a.m.– 6:00 p.m.	17.47	6289.2
Corridors 2nd F	Skylight atrium glazed roof	CF lamp	28	52 w	1.456	Time schedule off: 6:00 a.m.– 6:00 p.m.	17.47	6289.2
Total energy saving per year (KWh/ Y)								**43855.2 kWh/Y**
Total energy saving per year (MWh/ y)								**43.855 MW/Y**

Table 4. The effects of the Proposed Control system on cost savings.

Area estimation	Energy saving (kWh/year)	Electricity Tariffs for Governmental (Riyals / kwh)	Cost saving SR	Cost saving USD
Investigated atrium	43855.2	0.32	14033.664	3,740.51
Throughout Najran University	43855.2 X 25 colleges= 109,6380		350,841.6	93,512.86

4 Conclusions and Recommendations

This research combines daylight and energy assessment for the atrium and surrounding corridors in education buildings in a hot arid climate. Najran City has a clear sky throughout the year with abundant daylight to meet the demand for lighting a building during working hours. This study recommends building owners as well as designers to integrate electrical lighting-daylighting by intelligent lighting control, particularly time-scheduling control, for further energy saving in buildings.

Field measurements in atrium spaces and linked corridors at the College of Applied Medical Sciences, Najran University, were conducted. Daylight availability and indoor illuminance were recorded and analysed. The horizontal illumination level indoors ranged from 300 lux to 3 600 lux particularly during the midday due to the huge glazed roof and the clear sky condition of Najran City.

The amount of energy savings due to the lighting controls of time scheduling 6:00 am to 6:00 pm was calculated. The time-scheduling control is effective in a climate of clear sky throughout the year. The daily electrical lighting energy saving for the atrium space and linked corridors at the first and second floors was 121.82 kWh/day, whereas the annual lighting energy saving was 43856.6 kWh/year. The total annual energy saving from all 25 colleges in Najran University is 1096380 kWh/year. However, the total cost saving is about (93,512.86) USD.

It is noted that there are still potentials to reduce energy consumption in the university buildings by retrofitting the lighting control system in other atria and courtyards throughout Najran university campus.

However, the study recommends the following:

- Using an atrium in a hot arid climate should be considered to bring light to the centre of a large building. A daylight from a skylight atrium glazed roof should be controlled with shading devices to eliminate unwanted direct glares and prevent heat gain. An indoor illuminance of 100 lux can be, easily, provided by daylight for the atrium space and corridors at ground, first and second floors.

- The study found that the daylighting illumination level reached more than 5,000 lux and found an approximately 30 Klux in a certain time in the summer of June, so that the study suggests further research to assess the impact of roof shading systems such as motorised skylight blinds on controlling unwanted daylight glare in the atrium spaces.

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Case Studies on the Impacts of Climate Change on Historical Buildings in Northern Cyprus

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ABSTRACT

The changing in climatic conditions is one of the most significant issues in the twenty-first century. The literature suggests various approaches for the understanding of the harmful influences of climate change. Climate change is caused by increases in atmospheric greenhouse gases, deforestation, altering watercourses and human actions with tragic effect on the environment has turned into certainty, as that the procedure may not be over in a short period or medium period. Climate observations showed that climate change occurrence had unfavorable impacts on society and mostly on built environment. The most vulnerable buildings are the historical buildings. The impact of climate change on historical buildings should be studied very carefully to determine the meteorological parameters and changes which are the most critical for the protection of the cultural heritage. Prediction of the effects of climate change on built cultural heritage for the next 100 years is necessary to take every step to protect the historical buildings that are likely to be worst affected by climate change effects. Against this background, this paper reviews the physical and chemical deteriorations of historical buildings and changing energy consumption of historic buildings. The research exposed the risk to lose cultural heritage and rising energy demand in the Northern part of Cyprus as a case study. Structural engineers and architects should consider the dominant forces of climate change to protect the historical buildings but also to construct sustainable, feasible and durable buildings for future projects.

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1. Introduction

Climate is the statistics of weather conditions in the extended period. It differs from weather, by describing long-term conditions in a region. It provides functional survival needs like air, temperature, water, and wind during the lifespan of living things on the planet. Therefore, any changes in climate will have a direct and indirect effect on the health of people. It is very well known that global warming and hence the change in the climate is the consequence of human activities. The industrial revolution marked as the turning point of climate change. There is an incremental increase in greenhouse gas emissions to the atmosphere due to the industrial activities. The construction industry is one of the most important sector which releases vast amount of carbon dioxide (CO_2) emissions into the atmosphere and also generates a very significant amount of waste which is

difficult to deal with. According to IEA 2017, Buildings and construction account for more than 35% of global final energy use and nearly 40% of energy-related CO_2 emissions. Therefore, it is confirmed that the construction industry has a significant impact on climate change.

On the other hand, the changes in climate change have a detrimental impact on the buildings as well. The researchers have always been focusing on the damaging effects of materials used or the greenhouse gases (GHG) emissions caused by the construction industry. However, a little attention was paid on the fact that global warming and hence climate change also influence the quality, durability and safety of the buildings and hence the materials used. The CO_2 release from the buildings is mostly happening due to the fossil fuels used for providing heating and cooling purposes. Generally, fossil fuels are the most widely preferred sources to achieve primary world energy. In 2016, fossil fuel usage provided 80% of world energy (World Energy, 2019). Therefore, CO_2 and methane concentrations are increased as a result of the high amount of fossil fuel usage. These atmospheric changes with human-induced natural influences have changed the climate. Higher temperature rates, hot extremes, heat waves, heavy precipitation and decreases in snow thickness are some significant effects in climatic changing conditions. In brief, based on the current observations made by scientist it is clear those human activities have a detrimental impact on environmental health, and this change in environment also has a detrimental impact on the human health. On top of that, it is true to say that any negative impact on the environment would directly have an influence on every living and non-living things on this planet. Therefore, it can be stated that climate change which have been initiated by the human activities currently affecting their health but also everything else on this world. The construction industry was also initiated by the human beings to provide them shelters and since then not every progress was kept under control to observe any negative impact of all these developments would have on the environment or human health. For example, a high amount of nonrenewable energy use is at least one aspect which was supposed to be controlled in order not to increase any GHG emissions into the atmosphere. All the buildings are exposed to the environment, and hence they may be influenced negatively. Therefore, it is important to observe the contribution of historical buildings into energy consumption and what has influenced them till today by means of detrimental changes in the environment. As it was also mentioned by Ak, 2016; climate change may cause deteriorations on especially stone-based construction materials used in historical buildings. Climate change may lead to reduction of the material durability and may cause static problems for the building. The changes in temperature may have negative impact on the construction materials used in historical buildings; as of changes of the colours of stones by time. The main causes of the deterioration may be listed as: significant changes in air temperature, thermal expansions, solar and atmospheric effects, water and humidity, wind and most importantly deteriorations due to air pollution. All of these may not only cause deformation or deterioration of historical buildings but they may also cause disappearance of partial or whole structure within a period of time.

It is important to investigate and analyse the impacts of climate change on historical buildings since only very little known if and how climate change influences the historical buildings which are our cultural heritage. The impact of climate change on historical buildings should be studied very carefully in order to determine the meteorological parameters and changes which are the most critical for the protection of the cultural heritage. Prediction of the effects of climate change on built cultural heritage for the next 100 years is necessary in order to take every step to protect especially the historical buildings that are likely to be worst affected by climate change effects. Therefore, the main scope of this research is to investigate the impact of climate change on historical buildings and incremental growth of energy consumption in buildings. Particular emphasis is provided on the potential impacts of climate change on historical and monumental buildings by investigating different features of the buildings in a discussion. Energy consumption performances of the buildings are also discussed in this paper. A few recommendations will be made to represent possible alternative solutions to minimize energy consumption.

2. Materials and Methodology

2.1. Cyprus as a Case Study

Cyprus is the third largest island in the Mediterranean Sea. It is situated just in the middle of crossroads of three continents: Europe, Asia and Africa. A historical island like Cyprus owns the chance of having so many different cultural impacts on ancient buildings. This small island due to its strategic geographic positions has been visited, coveted, conquered and colonized many times during its 10,000- year history. It is pretty easy to observe the traces of each nation visited the island during the history including seeing Greeks, Romans, Byzantines, Lusignans, Genoese, Venetians, Ottomans, British, and Turks. The historical places and buildings exist in Cyprus provide the opportunity to observe the traces of each nation visited the island during the history.

Historic buildings are the national cultural value of each country, which is a bridge from past to present with extensions to the future (Tavukçuoğlu, 2000). They have undertaken a public mission for giving opinions to the next generations regarding the national heritage. In order to narrow the area of study, the historical buildings investigated are only chosen from Northern part of Cyprus.

2.2. Methodology

This research was undertaken according to personal observations regarding to the current conditions of historical buildings in Northern Cyprus. Specific, measurable parameters are taken into accounts which are temperature, rainfall, wind velocity and direction, the rate of evaporation and relative humidity. These parameters will be mentioned and discussed within the context of the study. In order to understand, investigate and able to

compare and analyses the past, present and future of the historical buildings and evaluate how much they have been influenced by climate change. This review paper answers two fundamental questions; which are:

- What are the impacts of climate change on historical and monumental buildings?
- How will energy demand be affected by climate change?

In order to compare and figure out the development of architectural features of the ancient buildings in the chosen area of the study; all available literature was also reviewed.

3. Findings and Discussions

3.1. Historical and Monumental Buildings

The observations made in the research study were supported with the information available in the literature. There are a few and limited data available on the structural information of the historical buildings so quantifying the findings is pretty difficult by means of evaluating the level of deterioration happens in the last 10 to 100 years. In order to quantify the observations made, this study needs to be supported with the old data regarding to the deteriorations happened on the historical buildings. This paper was undertaken with the scope and aim to act as an initial work which encourages future works to be done in this area hence we can really predict what could be happen in the coming 100 years to the historical buildings due to the effect of climate change and hence may be prevented to be happening.

In all over the island, it was observed during the construction of almost all ancient and historical buildings natural stones were used. In general, natural stones are used as the primary raw material to construct historical buildings. One of the main disadvantages of using natural stones is due to the fact that atmospheric pollutants combine with climatic factors, and they cause deteriorations in buildings depending on the type of stones. The conservation of stones is based on understanding the current situations of historical buildings. These situations include the geological characteristics identification of the existing structure, climatic conditions, impacts of air pollution and natural catastrophe. The weathering of stone occurs as a result of physical, chemical, mechanical and biological processes. Briefly, temperature effects, atmospheric effects, and living beings are mainly responsible for deteriorations of sandstone and limestone as investigated by Yaldız, 2010 and Ak, 2016.

3.1.1. Temperature Effects And Precipitation

Natural sandstone and limestone were the most commonly used construction materials for historical, cultural and monumental building types in ancient times due to their high resistance against to natural environmental conditions. Although they have high resistance, they are affected during the time cause of the world's climate change. The state of the stones changes the protection and usage status of the historic structures. The stone materials of historical buildings are affected generally by temperature variations and solar impacts. Various photos were taken in order to show the modifications these stones gone through due to the varied climatic conditions, i.e. sharp changes in temperature. According to the Department of Meteorology of Cyprus, it is said that climate change has a severe effect on Cyprus climatic conditions. The main changes have been observed on the amount of precipitation and mostly temperature. The annual precipitation values and degree of temperature are given as below:

- ✓ The average annual Precipitation in between 1991/1992 and 2007/2008 years (17 hydro-meteorological years) was found to be 457 mm or 9% lower than normal (503 mm, period 1961-1990).
- ✓ The average annual Temperature in the period 1991-2007 is 17,7^{0}C or 0,5^{0}C which was 17,2^{0}C higher than period 1961-1990.
- ✓ According to the above rate of changes, it is expected that by 2030 Precipitation will decrease by 10 - 15% and Temperature will increase by 1,0 - 1,5^{0}C compared to the normal values of the period 1961-1990.

(Department of Meteorology, 2019)

3.1.2. Thermal Expansion

The temperature difference between day-night and seasons of the year ends with volume change such as expansion and shrinkage. It is well known that temperature difference increases with climate change in all around the world. Moreover, consistent temperature variations create the cracks and fractures on stones in consequence of the fatigue material. Different enlargement amounts of stone material are an alternative influence of temperature. It occurs as the cause of temperature differences between internal and external sides of stone materials. The global temperature increment change is shown in Figure 1.

On the other hand, thermal expansions occur not only because of temperature changes but also freezing plays another role in contraction. Since water enlarges its volume later the freezing procedure, frozen water inside cracks causes broken pieces of stones. When the same process happens progressively many times, breaking of stones will take place frequently. Freezing-thawing leads to deformation of stones at the places, where it has a significant daily and seasonal temperature differences. Architects prefer to change stones when they deform 80%, during the restoration process of monumental structures. Temperature increase with a rate of 0.01°C each year observed in Cyprus Island during the 20th century.

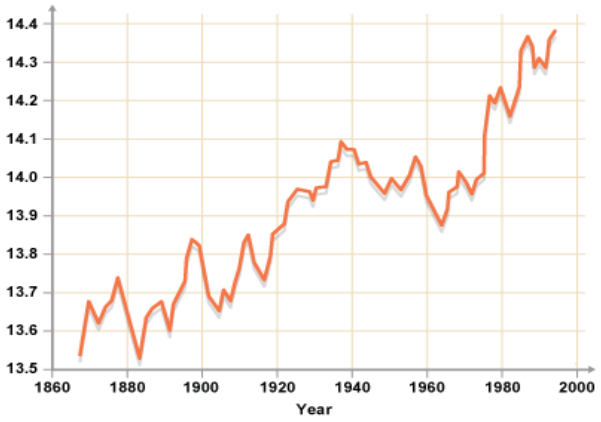

Figure 1 Global average temperature (°C) between 1860 and 2000 (BBC, 2018)

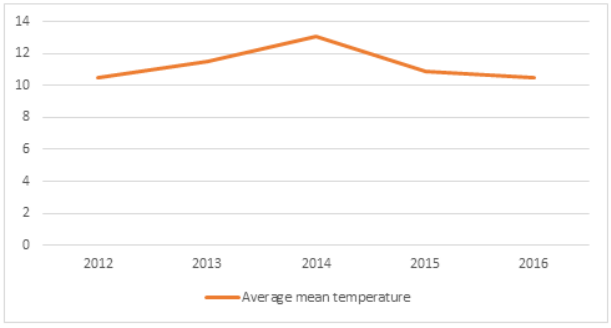

Figure 2 Average mean temperature (°C) on January 2012-2016 in North Cyprus
(TRNC SPO, 2019)

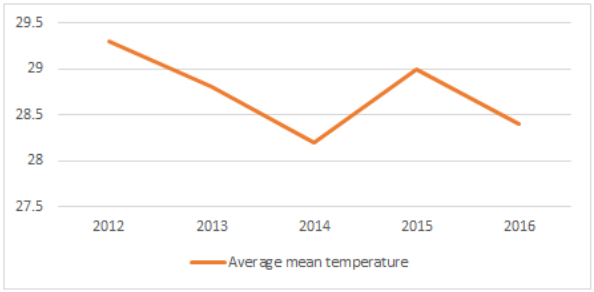

Figure 3 Average mean temperature (°C) on August 2012-2016 in North Cyprus
(TRNC SPO, 2019)

3.1.3 Solar Effect

Temperature differences between day and night result in changing the colors of stones. Figure 2 and 3 shows the differences in temperature during the winter and summer seasons in Cyprus in between 2012 and 2016 years.
Temperature differences between day and night result in changing the colors of stone as in Figure 2.
Therefore, faded surfaces take a matt and pale looking in natural construction stones depending on temperature changes. Dark spots are also observed in monumental and historical buildings as a solar effect. See Figure 4

Figure 4. Discoloration in stones of Great Inn (Büyük Han) in the Turkish Republic of Northern Cyprus (Media, 2018)

3.1.4. Atmospheric effect

Atmospheric motions and moisture are evaluated as hazardous factors towards keeping monumental buildings in safe. Although the stone substance has terrible weather condition resistance, it goes through deterioration after a while, and it sometimes destroys existing stones in monumental buildings. Massive damages on soft stones cause to particles that are brought by winds.

On the other hand, stones can experience cracks or fracturing into pieces in consequence of stresses under the effect of temperature variations, freezing-thawing, and moisture variation. Furthermore, under the effect of disturbed atmosphere organisms and water lead to chemical dissolution on stones. The dust layer increases its thickness in the course of time by generating dirty layer on stones. The classification of the type of deteriorations is in accordance with the effect of water and moisture, salts, winds and air pollution for the subtitles of atmospheric composition.

3.1.5. Water and Humidity

Humidity is known as one of the most critical deleterious determinants towards stone-made structures. Limestone dissolves under the effect of rainwater and CO_2. Furthermore, the acid rains are the threat of stones that are brought by the rainwater whose capillary rise in the building leads to undesired impacts on the material consumption. The soil layer between the earth surface and groundwater level keeps water by capillarity, which does not permit to get rid of drainage system usage. The high amount of humidity brings damages to the structure. Simultaneously, the saltactivation with the help of water and moisture also affect the building materials.

3.1.6. Wind

The transportation and installation of seed into cavities, joint point between walls and roofs with the effect of wind lead to mature trees on the neglected surfaces of historical and monumental buildings. Therefore, it helps to speed up decreasing the lifespan of the monumental buildings. Furthermore, if wind shows its negative impact with sand and sea salt; severe surface weathering will occur on the historical buildings. Water dissolved salts are transported inside the pores in the building materials, and water salts collect on the surface of stone or at the thin cracks of stone by the effect of evaporation. The presence of water-soluble salt particles in a stone-made structures leads to textural and mineralogical damages within the time. On the other hand, salt crystallization is another reason for deteriorations on monumental and historical buildings.

3.1.7. Air Pollution

Air pollution has a significant effect on stone materials. Gas and ion resolutions brought to the surface area of structures with water, rain; atmospheric motions, wind, snow, and rainfall lead to weathering on the outer surface of a stone. Chemical weathering changes the composition of stones with the help of chemical reactions like dissolution, hydrolysis, and oxidation of stone materials. Air pollution is mainly responsible for chemical weathering. Wind, relative humidity, fog, sunlight and solar radiation are well known meteorological factors that cause faded stones. The air pollution is directly proportional to the location of the place, where air pollution is the single factor on the brilliance loss of limestone.

3.1.8 Biological Activity

Biological activity has been affected by climate change in historical buildings and on cultural heritage materials. Fungal activity has adverse effects on cultural heritage. Lichens and mosses are formed in winter session due to climate and cause deteriorations on historic structures. Deterioration processes go along with biochemical transformations, which happen at specific temperatures in the development process of the organism. However, temperature, moisture, and nature of the substrate affect the development of organisms. Spores can germinate at temperatures above 0°C and moisture level of more than 70% (Leissner et al. 2015). Most fungi activity happens between 0°C and 50°C. Biological action is based on temperature and particular minimal moisture for growing. Mold growth plays another role in deteriorations of historical buildings. It expects the minimum temperature to starts for its activity. Sedlbauerisopleths system (Sedlbauer, 2001) offers simulated risks to determine the potential danger of mold growth. Mold risk index can be used to categorize their growth activity (Viitanen et al., 2007).Mold risk index;

- 0: No growing
- 1: Some growing observed together with the only microscopy
- 2: Moderate growing observed together with microscopy (coverage higher than 10%)
- 3: Some growing observed visually
- 4: Visually observed coverage by greater than 10%
- 5: Visually observed coverage by greater than 50%
- 6: Visually observed coverage 100%

Table 1 provides various pollutants and their impacts, especially on cultural materials.

Table 1 Pollutants and their impacts on cultural materials (Shaglouf et al., 2016)

Types of Cultural Properties	**Effects**	**Pollutants**
Metals	Corrosion, discoloration	Acid rain, SO_x, NO_x, Cl
Stones	Discoloration, deterioration	Acid mist, SO_x, NO_x, Cl
Wooden	Deterioration, discoloration	Acid rain, SO_x, NO_x, Cl
Wall paintings	Peeling, discoloration	Acid mist, SO_x, NO_x, Cl
Glass	Cloudiness	Acid rain, SO_x, NO_x, Cl
Oil paintings	Ammonia	Deterioration of oils
		Cloudiness of varnish

3.2. Energy Consumption

Many researchers have conducted studies regarding climate change effect on energy consumption. Generally, gas and electricity needs for the heating decrease and increase for cooling day by day in different places of the world. There is incremental growth concerning about climate change and its effect on energy usage. Heating, air conditioning, and ventilation energy demand cover 34.8% of building energy consumption in the United States (Jiang et al. 2017). Moreover, humidity has an essential impact on electric energy consumption. When high temperature combines with high moisture, it directly raises the energy requirement for climate control. For instance, high amount of air conditioning usage throughout hot and humid summer sessions and the usage of electric energy and gas for heating purpose in winter session months, residential and commercial buildings in Florida counted 23.7% and 28.6% of increasing energy need in 2013 according to U.S Energy Information Administration in the year of 2015. Intergovernmental panel on climate change (IPCC) estimations show increment in global average face temperature within varied forms. Watkins et al. (2002) indicated that buildings would be warmer so an extra cooling energy demand will be required. Therefore, sustainable low energy buildings are alternative design models to provide thermal comfort under the

effect of warmer summer sessions. Wang et al. (2010) found the climate change effect on residential buildings by using five different regional climates in Australia with regards to heating and cooling energy requirements. Therefore, energy efficient residential buildings need less energy change requirement cause of climate change according to this study. There are intensive researches on the impact of climate change on buildings all over the world. Humidity and average global temperature will increase according to findings, so it will directly affect building energy consumption exclusively in subtropical climatic areas. Moreover, the impacts on energy usage are based on climatic zones, building types and area (city, rural) of the buildings as well. Architects and engineers play an essential role in designing and constructing energy-efficient buildings. (Hurlimann et al., 2018)

The logic of building energy demand modeling is by a prediction of future demand or increasing energy efficiency. Generally, simulations are performed with BEND (Building Energy Demand) model that is a platform for analyzing building benefits from energy plus.

Peak demand is a critical point for developed countries. In many studies, energy consumption is associated with annual or monthly heating degree-days (HDD) and cooling degree days (CDD) in the same period (Chaturvedi et al.,2013; Kaufmann et al., 2013). BEND is a part of the model from the Platform for Regional Integrated Modeling and Analysis (PRIMA), improved by Pacific Northwest National Laboratory (Kraucunas et al., 2014). The following points are of significant importance in such analysis processes

- Detect the number of parallel climate regions for the geographical region of interest. Climate conditions are associated with calculation time as well.
- Determine the number of buildings and characteristic features of these buildings. The building's features could change in the course of time.
- Use climatic data in the convenient form for adjustment according to actual historical weather and simulate data regards to climate change estimations.
- Collect real energy consumption information for areas and prepare the sample from old time records.
- Analyze the following climatic data by using the draft model to calculate further building energy demand and peak electric energy need under the impact of estimated future climatic conditions.
- Obtain the building energy consumption profiles for the geographical area of study.

Dirks et al. (2015) studied energy spending and peak demand in buildings by thinking of a comprehensive regional perspective in the United States of America. They used the computational assessments of scenarios change for Delta Ecosystem (CASCaDE) dataset to predict future climate conditions, and then they transformed climatic information into BEND model. In CASCaDE dataset rainfall for day by day, maximal and minimal temperature from GCMs (General Circulation Models) were considered. The results are obtained for 2004, 2052 and 2089. Temperature data separated into four sessions for any year as follows.

- Spring session (Includes March, April, May)
- Summer session (Includes June, July, August)
- Autumn session (Includes September, October, November)
- Winter session (Includes December, January, February)

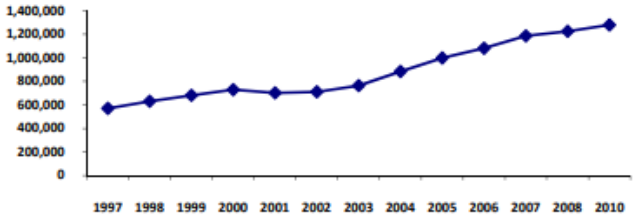

Figure 5 Electricity generation (Kwh) in 1997-2010, North Cyprus (Ozerdem and Biricik, 2011)

3.3. Energy Saving Recommendation

Energy consumption reduction is a type of challenge in building design against climate change conditions, and it needs an extra budget. Thermal achievement improvement of building by applying phase change material (PCM) is a type of technique to minimize energy consumption for future climate conditions. PCMS is added to building envelope to charge and leave energy as hidden heat in low-temperature intervals that causes incremental growth for building's thermal mass. As a summary, PCM decreases heating loads, loads of cooling, carbon emission and offers comfortable living conditions.

In North Cyprus the electricity generation in increasing very sharply in parallel to the need of energy need as shown in Figure 5. Therefore, every step should be taken to reduce the consumption of energy. The buildings consume 20-40% of the energy reserve according to current studies (Heier et al. 2015; Saffari et al. 2016). On the other hand, heating ventilation and air conditioning (HVAC**)** covers the %50 of the building energy (Saffari et al.2016; Marin et al. 2017). Moreover, buildings contribute to greenhouse gas emission as the amount of 30-40% (Hussain et al. 2017; Vicente et al., 2014).

Different types of technologic innovations have been offered to reduce the building energy demand and develop thermal comfort. Isolation materials, double-glazed reversible window arrangement, heat insulating solar glass, hybrid walls with the collector and thermal power generators are kind of examples for reducing energy consumption and increasing thermal comfort. Reinforcing building envelopes together with thermal insulation is a method to decrease heat distribution from interior to exterior. This method increases energy efficiency so, reduces the amount of greenhouse gas emission. Building envelope and smart HVAC equipment are good ways to obtain a sustainable energy performance. (Soares et al., 2014) discovered that PCM increases energy yield by 10-60% according to climate region

when applying to drywall inside lightweight steel-framed buildings.

Researchers made a test to identify the energy recovery potency of PCMS in buildings under the effect of future climatic cases (Gassar et al. 2017). The experimental description is presented in the following.

- The building was an office building with three-story and an area of 1,660.73 m^2.
- The ratio of the window to the wall is 33% of the total wall area.
- Three types of PCM was used (BİOPCM, DUPOnEnergainPCm, MRUBITHRMPCM).
- The climatic zones considered in addition to humid tropical and subtropical climates.
- Three climatic zones were Seoul, Tokyo and Hong Kong.
- The further climate duration contains the years 2020, 2050 and 2080.

This study concludes that PCM together with suitable melting stage temperature into a building's envelope can save energy in the course time cooling and heating periods.

4. Observations on the Impact of Climate Change on Historical Buildings in Northern Cyprus

Several observations were made in some selected historic buildings in Northern Cyprus mainly focusing on the capital city of the island. Several photos of the selected historical buildings are provided below to demonstrate the effects of climate change on monumental buildings. As it can be easily understood from the photos taken by the authors of this paper; it is clear that increasing rate of temperature and unexpectedly increasing rate of rain falls has caused an increase the amount of humidity. The detrimental impact of this humidity was felt obviously as soon as had a look at the buildings.

Figure 6 represents Bedesten or Bedestan which is a historical building in the Selimiye quarter of North Nicosia, located directly beside the Selimiye Mosque (Figure 7). The structure has a long and complicated history spanning more than one thousand years.

In almost every single historical building (see Figure 6, 7, 8, and 9, respectively) exists in Nicosia; generally, algea and black color formation was observed on yellow which is used for the façade of the all buildings observed. In addition, as seen in the last photo of the Selimiye Mosque, it was observed that the plant was grown on the arches.

Figure 6 Bedestan

Figure 7 Selimiye Mosque

Figure 8 S*ultan Mahmut II* Library

Figure 9 An old house located in the center of Nicosia

5. Discussions and Conclusions

According to the observations made and available local resources, it is known that the historical buildings exist on the island were constructed mainly using stones which were accepted as the natural construction materials at the time they were used. Based on the observations made it is clear that serious deteriorations occurred on the buildings by time.

The deteriorations observed might be occurred due to the age of the structures but mostly due to the environmental conditions and factors. As it was mentioned earlier in this paper, significant and sudden changes in temperature, rainfall level, wind, and humidity are the main causes of these damages on the historical buildings. It is apparent that more is expected to be occurred in the upcoming years if no further action is taken in order to protect the historical buildings.

Overall it can be concluded that:

- The vulnerability of historical and monumental buildings in Cyprus increases with many types of deteriorations cause of climate change impact.
- Cultural heritage works have no long lifespan due to unexpected changes in climate.
- New design standards can be generated for future design models by considering the current investigations on historical and monumental buildings.
- Energy consumption will increase not only in Cyprus but in the entire world, especially for cooling purposes.
- Thermal isolation material usage in buildings can be mandatory with laws to encourage less energy consumption.
- Smart heating ventilation and air conditioning system has promise future to regulate energy consumption.
- Energy savings can be supported by developing new construction materials and architectural aspects in addition to current applications.
- Governments should play more roles to increase the awareness of climate change.
- More enforcement should be put into action in order to increase the use of renewable energy resources for heating and cooling purposes. Hence, climate change and global warming can be controlled, and their detrimental impacts can be reduced or even stopped.

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Valuing Sustainability of Adaptable Infrastructure Using ROA-SEC: A Hybrid Approach

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ABSTRACT

Infrastructure providing fundamental services for societies may become obsolete under changing environments such as climate or demographics changes, creating the need for adaptability. Designing infrastructure for adaptability may affect life cycle costs as well as environmental and social issues such as resources consumption, waste production or disruption to services provided. Sustainability valuation of adaptable infrastructure is thus required. The Real Options Analysis (ROA) is widely used to evaluate financial viability of investing in adaptable infrastructure. But, the environmental and social aspects have been barely noticed and incorporated. Hence, a valuation method is required to properly address all aspects of sustainability. This paper bridges the gap and advances the literature by presenting a methodology for designed-in adaptability valuation, considering all the sustainability aspects. To this end, a hybrid approach is suggested through integration of Social and Environmental Costing (SEC) with ROA, providing a single measure for sustainability of adaptable infrastructure. In this approach, the outputs of Life Cycle Assessment (LCA) tools are monetized using SEC methods; and then incorporated in the ROA that is built on the probabilistic Discounted Cash Flow (DCF) analysis, suitable for engineering applications. The application of the proposed approach is illustrated on a case example involving seawalls under changing climate effects. For the case example, including sustainability issues in the analysis improved the viability of designing in adaptability. This conclusion cannot be generalized and each situation requires an individual analysis. However, the proposed approach and methodology will be the same in all the situations.

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1. Introduction

Infrastructure providing fundamental services for societies may become obsolete under changing environments such as climate or demographics changes. Infrastructure adaptability or flexibility is suggested as a key solution when design requirements change over time (Conrad and Raucher, 2013; Scholtes, 2007; Slaughter, 2001; Taneja et al. 2012). Given that infrastructure is intended for long term operation, it will be adapted to changes someway in future. Thus, developers are caught in a dilemma to whether or not design infrastructure for adaptability. This implies the notions of *non-designed-in (or fortuitous)* adaptation versus *designed-in (or in-built)* adaptation (Carmichael and Taheriattar, 2018) – where an option, a right but not an obligation, is embedded in design to accommodate uncertain changes (Wang and de Neufville, 2005). The latter, which is the focus of this paper and compared against the former, often requires or is perceived to require extra upfront cost and effort. While, possible fortuitous adaptation in future may lead to greater sustainability issues, such as enormous adaptation costs, resources consumption, or disruption to substantial services provided for the society.

Despite the literature acknowledges infrastructure adaptability to enhance sustainability through extended useful life (Moffatt and

Russell, 2001; Taneja et al. 2012; Wilkinson et al., 2009), it stops short in valuation of designed-in adaptability (Gosling et al., 2013; Schneider and Till, 2005; Slaughter, 2001). Real Options Analysis (ROA) is used to evaluate financial viability of investing in adaptable infrastructure (Carmichael et al., 2011; Copeland and Antikarov, 2001), but disregards social and environmental aspects. A few attempted considering sustainability issues in adaptability valuation using LCA tools (Carmichael and Taheriattar, 2018; Fawcett et al., 2014; Moffatt and Russell, 2001), while still have limitations in terms of incorporating uncertainty or interpreting the results (Fawcett et al., 2014).

Therefore, this paper aims to properly incorporate social and environmental issues and associated uncertainties into the sustainability analysis of adaptable infrastructure. Thus, the paper suggests integration of ROA with Social and Environmental Costing (SEC), providing a compatible extension to ROA application. The proposed approach also gives a single sustainability measure suitable for comparison and decision making purposes, as designed-in adaptability is compared against a base case of non-desigend-in adaptability. The study will be of interest to people within the construction industry as well as investors or corporates with social and environmental liabilities. Using this approach, they will be able to figure out whether and to what extent incorporating specific adaptability in any design and construction is viable, from sustainability viewpoint.

The paper firstly presents a literature review on infrastructure adaptability and sustainability and associated valuation approaches. The proposed approach is then introduced, followed by a discussion on commonly used SEC techniques. Finally, the proposed approach on adaptability valuation is demonstrated on an Australian case example (involving seawalls under changing climate effects), with arguments on the sustainability value of the incorporated adaptability. The analysis is done from public and investor viewpoints to reflect different views and show the capability of the proposed approach as well. The paper's methodology, but not necessarily the designs and assumptions used in the case example, can be applied to other situations.

2. Background

With responding to changes imposed on infrstarture, there exist two strategies of mitigation and/or adaptation. With climate change for example, the infrastructure may be designed and constructed in a way to reduce greenhous gas emissions mitigating the climate change and/or in a way to adapt to the impacts of the changing environment (Smit and Pilifosova, 2001). The adaptation strategy is the focus of this paper. Adaptability (the ability to adapt) causes the infrastructure to remain in operation by responding to future changes; thus enhances sustainability (Conrad and Raucher, 2013; Gosling et al., 2013; Scholtes, 2007; Taneja et al. 2012; Wilkinson et al., 2009). Schneider and Till (2005) state that *'sense tells us that adaptability is more beneficial in the long term because obsolescence is limited'* (Schneider and Till, 2005, p.162). The advantage of adaptation and having adaptability in general (versus no adaptability) has already been supported in the literature by quantitative assessments (Gosling et al., 2013; Moffatt and Russel, 2001). However, this should not be confused with the designed-in adaptability in particular (versus non-designed-in adaptability), which may or may not be worthwhile.

2.1 Designed-in Adaptability Valuation

Designed-in adaptability refers to an embedded ability to adapt, where the infrastructure is designed for adaptability to accommodate future changes while knowledge on the changes is unclear at the time of design (Slaughter, 2001; Gosling et al., 2013). Wang and de Neufville (2005) introduce designed-in adaptability as the ability developed by changing the technical design. Engel and Browning (2008) look at designed-in adaptability as the application of options theory in engineering design. Carmichael (2014) also talks of designed-in or deliberate adaptability allowing for future possible changes to infrastructure in response to future uncertain circumstances.

Given that designed-in adaptability provides infrastructure with an option (a right but not an obligation) to adapt to changed circumstances, ROA is required for valuation (Carmichael et al., 2011; Copeland and Antikarov, 2001). ROA based on financial options analysis such as Black-Scholes equations and simulations have been used (Copeland and Antikarov, 2001; Kodukula and Papudesu, 2006). However, such methods are complex and not suitable for valuation of real assets (Howell et al., 2001; Kodukula and Papudesa, 2006; Lewis et al., 2008). As such, there has been a reluctance among practitioners to adopt ROA (Block, 2007; Van Putten and MacMillan, 2004) due to i) inconsistency of the valuation models with Discounted Cash Flow (DCF) analysis which is commonly used in practice (Barton and Lawryshyn, 2011), and ii) lack of understanding of ROA, where incorrectly perceived as a substitute but not a supplement to conventional methods (Block, 2007; Kodukula and Papudesu, 2006). As a result, consistent versions of ROA have been developed using spreadsheet calculations (Carmichael et al., 2011; de Neufville and Scholtes, 2011).

It has been suggested to build ROA on traditional DCF calculations (Barton and Lawryshyn, 2011; Carmichael and Balatbat, 2009; de Neufville et al., 2006; Van Putten and MacMillan, 2004). de Neufville et al. (2006) introduce a computer-based spreadsheet model for estimating real options value using Monte Carlo simulation. However, the model still has shortcomings, namely i) taking into account the downside potential of investment where the option is not exercised (Howell et al., 2001), ii) the need for allocating probability distributions to analysis inputs, and iii) providing little insight into the calculations (Carmichael et al., 2011; Wang and de Neufville, 2005).

Carmichael and Balatbat (2009) suggest utilizing probabilistic DCF analysis with the second order moment approach to estimate real options value. The approach requires characterizing cash flows with their moments and fits a distribution to total present worth for valuation. This method only looks at upside potential of investment and is more appealing to engineers.

Such efforts made to adjust ROA for financial valuation of infrastructre adaptability, but the social and environmental aspects barely noticed. A few studies attempted incoporating social and

environmental issues in adaptability valuation, but using inadequate approaches. For example, Fawcett et al. (2014) evaluate costs and environmental impacts of flexible infrastructure, using Monte Carlo simulation with abovementioned limitations, while ignoring the social aspect. Carmichael and Taheriattar (2018) suggest LCA approach combined with ROA to reveal the potential for enhancing financial viability of adaptable infrastructure by inclusion of both social and environmental issues. However, the uncertainty of social and environmental intangibles is not incorporated in Carmichael and Taheriattar (2018), the uncertainty of social and environmental intangibles is not incorporated. Hence, this paper aims to fill the literature gap by presenting an approach that integrates all sustainability aspects and captures the uncertainty to value designed-in adaptability infrastructure. To this end, the existing sustainability assessment techniques are first reviewed to clarify the proposed approach.

2.2 Sustainability Assessment Techniques

With sustainability comprising of financial, social and environmental criteria, a multi-objective situation arises for sustainability assessment. There exist assessment techniques combining social, environmental and financial measures, which vary in ways of dealing with sustainability issues, namely measurables and non-measurables (Dompere, 1995). Measurables can directly be measured and expressed quantitatively, typically using LCA tools (ISO, 2006; Lehmann et al., 2013). The measurables can be expressed using monetary and non-monetary terms e.g. carbon emissions in ton CO2-e. Non-measurables are those with inherent subjectivity, unable to directly be measured in numbers, and typically expressed using linguistic terms e.g. low, moderate, high. A summary of the techniques follows.

Fuzzy-based technique links non-measurables' linguistic expressions to fuzzy set membership (Tan et al., 2011). Fuzzy ratings of sustainability issues can be weighted and summed to create an overall fuzzy rating (Siew et al., 2016). The approach offers advantages in terms of dealing with subjectivity; however, it has issues with regard to the definition of fuzzy ratings and weightings as well as the integration of outcome with measurables.

Multi-Attribute Decision Making (MADM) techniques such as TOPSIS or SAW (see for example, Tzeng and Huang, 2011) combine measurables and non-measurables. In this technique, the alternatives are scored based on pre-defined scales for measured quantities or linguistic expressions; the scores are then normalized and weighted to calculate the alternatives' fitness. Sustainability reporting tools are a particular example of this technique with already normalized and weighted scoring model (Rogmans and Ghunaim, 2016). Such techniques may be criticized because definition of scales, allocation of scores and weightings are subjective and difficult to reach a consensus on.

Social and Environmental Costing (SEC) technique combines sustainability criteria through monetizing social and environmental impacts or liabilities, based on 'polluter pays principle' (de Beer and Friend, 2006; Steen, 2005). The idea of using life-cycle costing in conjunction with LCA previously supported in the literature (Dascalu et al., 2010; de Beer and Friend, 2006; Parker, 2000; Steen, 2005) and followed by a code of practice for environmental life-cycle costing (Swarr et al., 2011). According to EPA (1995), social and environmental issues directly or indirectly incur costs on individuals, organizations and society. SEC attempts to extend market boundaries to non-market objects (Dompere, 1995; Lohmann, 2009; Mirasgedis et al., 2000), such that renews the conventional appraisal by inclusion of social and environmental externalities for correct investment decisions (Dascalu et al., 2010). Some examples include converting emissions or pollution to dollars using carbon credits or pollution rights traded in the market (Godoy and Saes, 2016; Lohmann, 2009). SEC eliminates the need for impact categories and weighting of inventory data (Swarr et al., 2011); however, choice of suitable indexes and monetization methods might be challenging (de Beer and Friend, 2006; Dompere, 1995). The SEC technique is employed in this paper, since it matches ROA with financial basis. SEC has the capability of merging the concepts of sustainability and investment in adaptability by presenting a measure that is to be paid by investors (Dascalu et al., 2010). The single measure is also desirable for comparison and decision-making, which is the purpose of this paper.

2.3 SEC Methods

Social and environmental issues are costed in different ways, categorized based on the 'strategies to deal with sustainability issues', namely prevention, toleration and restoration (Dascalu et al., 2010; Parker, 2000). Such categories are associated with costing only and should not be confused with the 'strategies to deal with changes imposed on infrastructure', namely mitigation and adaptation. The categorization is intended to organize, but not to limit, the possible costing methods. A selective overview of commonly used SEC methods follows.

Prevention Costing Approach

Policy tools – taxes, subsidies, penalties and fees or charges on environmental loadings (Dascalu et al., 2010; Godoy and Saes, 2016; Parker, 2000) e.g. permission fees for waste disposal (Parker, 2000), penalties on excessive wastewater discharges or noise/water pollution offences (de Beer and Friend, 2006). *Insurance value* – premium paid in advance in proportion to potential damages to individuals, materials and biodiversity (de Beer and Friend, 2006; Leopold and Leonard, 1987). *Pollution/hazard control cost* – expenditures on control measures preventing damages due to pollution or safety incidents e.g. building noise barriers or using loading platforms (Wang et al., 2019). *Disturbance prevention value* – reward/penalty assigned to early/late completion of a project (Gilchrist and Allouche, 2005).

Toleration Costing Approach

Health/safety cost – direct costs of using health services i.e. charges for using hospital treatment facilities (Song, 2018).
Loss of productivity/contribution – lost earnings due to disturbance to operation e.g. reduction in machinery's production or loss of human capital i.e. due to health and safety issues or lower worker

employment (Dinwiddy and Teal, 1992; Leopold and Leonard, 1987; Sah and Stiglitz, 1985). *Delay cost* – losses due to people's delays caused by construction works e.g. lost earnings plus cost of extra fuel consumption due to traffic disruption (Gilchrist and Allouche, 2005).

Restoration Costing Approach

Remediation cost – cost of remedial process of unwanted construction by-products i.e. removal and treatment of waste materials or pollutions in the form of air emissions or soil and water contamination (de Beer and Friend, 2006; Parker, 2000). *Replacement cost* – cost of minimizing inconvenience due to construction, through replacing affected facilities with similar alternatives, either temporarily or permanently (Gilchrist and Allouche, 2005).

Suitable methods should be identified for each specific issue and situation. Target community should also be specified for a rational costing of sustainability issues; people may emphasize the issues which are affected by or pay for (Dompere, 1995; Steen, 2005). The outcomes of SEC methods can be used for valuation of adaptable infrastructure using ROA-SEC approach which is proposed in the following.

3. ROA-SEC: A Proposed Approach

3.1 Outline

ROA using probabilistic DCF analysis with second order moment approach is here proposed to be adapted for sustainability assessment. A hybrid approach is suggested such that ROA is integrated with SEC, using LCA outputs. Figure 1 displays the ROA-SEC scope within the whole picture of sustainability assessment approaches reviewed in the literature. The ROA-SEC is used to decide whether to design infrastructure for adaptability or not. To this end, designed-in adaptation (denoted A) is compared with a base case of non-designed-in adaptation (denoted NA):

- A. Where adaptability features are designed and built in ab initio, with the view that adaptation may (but not necessarily) take place in the future depending on future circumstances.
- NA. Where infrastructure is designed and built without adaptability features in mind, while future adaptation may still be fortuitously possible.

The alternatives are examined over the infrastructure service life. Financial cash flows estimated using conventional methods together with social and environmental costs generate inputs of the ROA-SEC model which follows.

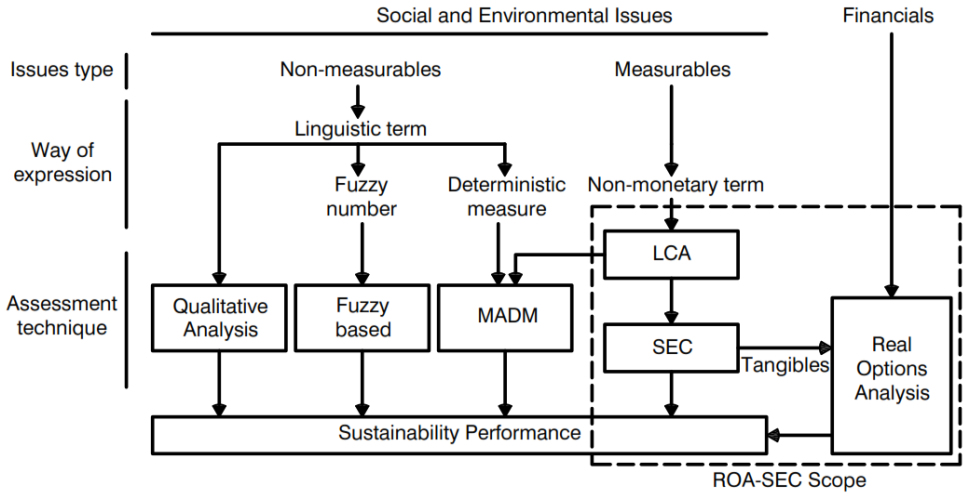

Figure 1 ROA-SEC scope – sustainability valuation of designed-in adaptability

3.2 Formulation

The options analysis follows Carmichael et al. (2011), which is capable of considering all the cash flows over the infrastructure service life. However, only monetary flows at time of adaptation, T, are considered in this paper. The time T is allowed to vary, to show the relationship between time of adapting and adaptability value. Expected values, E[ ], and variances, Var[ ], of all costs for both A and NA at T are estimated. Here, optimistic (a), most likely (b) and pessimistic (c) values are estimated as is done in the planning technique PERT. This leads to: expected value or mean $= (a + 4b + c)/6$, and variance $= [(c-a)/6]^2$. Because estimates for A and NA are based on similar assumptions, a strong correlation (approximately one) between the estimates would be assumed. For each adaptation form, the monetary flows of social and environmental issues are assumed to be perfectly correlated

to financial flows, as they are all proportional to quantity take-offs. Should this not be the case, the formulation can be adjusted.

To ascertain the value of adaptability over conventional practice, the difference between NA and A is looked at. Let X_T be the net cost at time T. That is,

$$X_T = (NA_{T,F} - A_{T,F}) + \sum_i (NA_{T,SE_i} - A_{T,SE_i})$$

where A_T and NA_T are the cost, at T, of A and NA respectively; F denotes financial cost component and SE_i denotes social/environmental cost component of ith sustainability issue. Then, the expected value E[X_T] and variance Var[X_T] become

$$E[X_T] = E[NA_{T,F}] - E[A_{T,F}] + \sum_i E[NA_{T,SE_i}] - E[A_{T,SE_i}]$$

$$Var[X_T] = \left(\sqrt{Var[NA_{T,F}]} - \sqrt{Var[A_{T,F}]} + \sum_i \sqrt{Var[NA_{T,SE_i}]} - \sqrt{Var[A_{T,SE_i}]} \right)^2$$

These are discounted to give the moments of the present worth, PW, of the difference.

$$E[PW] = \frac{E[X_T]}{(1+r)^T}$$

$$Var[PW] = \frac{Var[X_T]}{(1+r)^{2T}}$$

where r is the interest rate. Calculation of the adaptability value follows,

$$\text{Adaptability value} = \Phi M$$

where $\Phi = P[PW] > 0$, P is probability and M is the mean of the present worth upside measured from PW = 0. To calculate Φ and M, and knowing E[PW] and Var[PW], any distribution can be fitted to PW, but it is anticipated that most people would use a normal distribution.

This adaptability value is then compared with the total cost of building in adaptability at time 0 (including monetized intangibles). Viability is established for designed-in adaptability when the adaptability value exceeds this initial cost.

3.3 Incorporating Intangibles Uncertainty

Shadow prices and subsequent SEC outputs are highly uncertain (de Beer and Friend, 2006; Mirasgedis et al., 2000, Steen, 2005). The uncertainty of intangibles' costs should be incorporated into the valuation model (Clarkson and Deyes, 2002). Given that sustainability issues may be costed using a single or multiple methods, it is suggested here to deal with the uncertainty using either of the following two propositions.

Prop.1. In case the intangible cost, Y, is estimated using a single method because of limited data availability or general agreement on reliability of the method, the three-point estimates of optimistic (d), most-likely (e) and pessimistic (f) are utilized. As done for financial estimates, the expected value, E[Y], and variance, Var[Y], of intangible cost then become

$$E[Y] = (e + 4d + f)/6$$

$$Var[Y] = [(f - e)/6]^2$$

Prop.2. In case there exist multiple methods for estimation, the uncertainty of the intangible cost associated with method j, y_j, j = 1, 2, …, n, is similarly captured using the three-point estimates, which give the method's expected value, E[y_j], and variance, Var[y_j]. There might be quite large differences between the methods' estimates. Each method is given a normalized weight, w_j, which basically reflects the existing view on reliability of the method. The reliability weight can be specified in different ways. It is here assumed to be inversely proportional to the variance; hence a method with smaller variance in estimates is anticipated to be more reliable (Strutz, 2016; Taylor, 1997). The reliability weights then become

$$w_j = \frac{1/Var[y_j]}{\sum_{j=1}^{n} 1/Var[y_j]}$$

Given that SEC methods are typically different in terms of the logic of monetization, the estimates obtained using various methods are anticipated to be uncorrelated. For this situation, the expected value, E[Y], and variance, Var[Y], of the intangible cost become

$$E[Y] = \sum_{j=1}^{n} w_j \times E[y_j]$$

$$Var[Y] = \sum_{j=1}^{n} w_j^2 \times Var[y_j]$$

The ROA-SEC approach incorporating intangibles uncertainty is demonstrated on a case example in the following.

4. Case Example – Rock Seawalls

Seawalls in Australia are conventionally designed to accommodate water depth at the toe and breaking waves load (NCCOE, 2012). With sea level rise, the idea of designing seawalls for adaptability comes in mind. The case example here involves upgrading a 100-metre long section of rock seawall (A form) with incorporated designed-in adaptability features, namely 1) use of bigger rocks, sufficient for greater wave heights, and 2) parapet wall of bigger foundation, capable of being heightened when sea level rise exceeds the design level. The features allow the A form to be adapted with minor effort; however, the NA form will require placing a layer of bigger rocks and rebuild the parapet wall for adaptation. Figure 2 highlights the rock seawall adaptability and adaptations (bold lines indicate designed-in adaptability features and dashed lines indicate future adaptation measures).

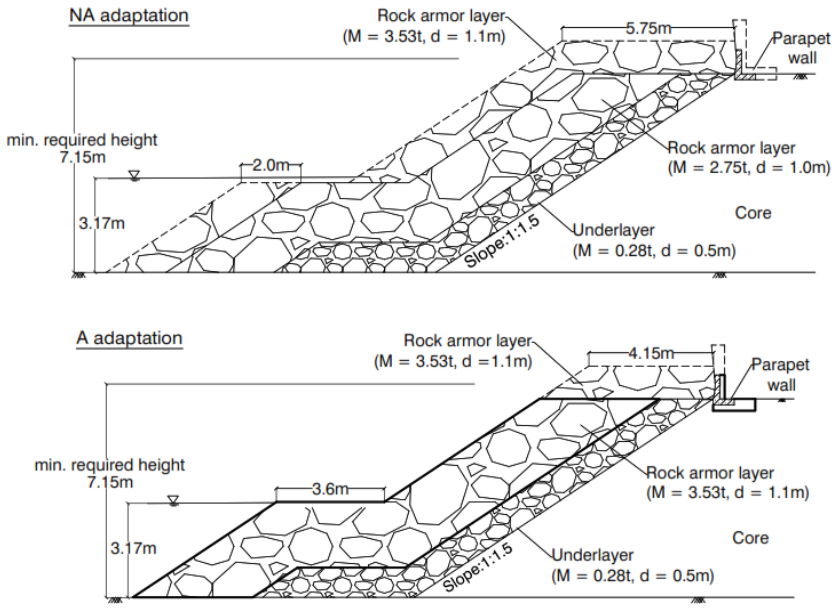

Figure 2 Rock seawall adaptability and adaptations – A vs. NA designs

It is assumed that the two forms of adaptation only differ at time 0 (initial design) and time T (time of adaptation). The different designs lead to differences in quantity take-offs as illustrated in Table 1. The initial cost of incorporating adaptability in design is estimated to be $57.7k (detail of financial cost estimating is omitted here for space reasons). The quantity take-offs are then used to calculate the differences in sustainability issues (A form minus NA form) as given in Table 2.

Table 1 Rock seawall adaptations – differences in quantity take-offs between A and NA forms

Time	A: Designed-in form	NA: Non-designed-in form
k = 0	• Extra mass of bigger rocks = 544 t Parapet wall foundation of bigger size: • Extra amount of concrete = 50 m^3 • Extra amount of reinforcement = 5.9 t	
k = T	• Added rocks = 880 t Parapet wall enlargement: • Concrete = 40 m^3 • Formwork = 200 m^2 • Concrete drilling = 500 no. • Reinforcement = 4.7 t	• Added rocks = 3296 t Parapet wall enlargement: • Concrete = 90 m^3 • Formwork = 300 m^2 • Concrete drilling = 1500 no. • Reinforcement = 10.6 t

Table 2 Summary of differences (A – NA) in environmental and social inventory flows

Sustainability issue	At k = 0	At k = T	Combined, k = 0 and T
Environmental			
Materials consumption (t)	664	-2,536	-1,872
Energy use (GJ)	185.2	-447.5	-262.3
Emissions (ton CO2-e)	20.2	-32.1	-11.9
Solid wastes (t)	29.3	-122.9	-93.6
Water pollution (kg)	35	-160	-125
Social			
Worker employment (h)	213	-855	-642
Safety incidents (number of injuries)	0.0070	-0.0282	-0.0212
Heath damage – noise exposure (h)	626	-12,408	-11,782
Inconvenience – traffic disruption (veh.h)	155	-686	-531

Negative values indicate that the NA form leads to greater sustainability issues compared to the A form

The extra upfront cost and sustainability issues for the A form are traded off against those of the NA form at adaptation time. Further detail on quantification of sustainability issues using LCA is relaxed and only the integration of SEC with ROA is focused here.

4.1 Analysis: Outline

The analysis is done from two different viewpoints: 1) *public viewpoint,* from which monetization of all the issues is attempted, reflecting the public awareness about sustainability (Parker, 2000), and 2) *investor viewpoint,* which only looks at the intangibles that are perceived by the author to be priced in the market within the decision timeframe (Swarr et al., 2011). For example, investors may be under no obligation to pay for not creating jobs or decreasing neighbors' productivity. Also, the environmental issues of materials consumption and energy use are excluded for both viewpoints because of lack of data on associated shadow prices. Note that the paper emphasizes on the methodology; others may look at different intangibles to reflect the investor or public viewpoints, but the method will remain the same. Table 3 illustrates the identified issues, the adopted SEC methods, and the way of incorporating associated uncertainty as discussed earlier in Section 3.3.

Table 3 Case example: sustainability issues and adopted SEC methods

Sustainability issue	SEC methods	Incorporating uncertainty by
Materials consumption	-	-
Energy use	-	-
Emissions*	Carbon tax*, Damage cost	Prop. 2
Solid wastes production*	Waste treatment cost*	Prop. 1
Water pollution	Remediation cost	Prop. 1
Worker employment	Contribution to society, Comfort value	Prop. 2
Safety incidents*	Insurance value*, Loss of contribution*	Prop. 2
Heath damage	Loss of productivity	Prop. 1
Inconvenience*	Delay cost, Replacement cost*	Prop. 2

Investor viewpoint analysis only looks at *

4.2 Shadow Price Estimates

Unit price of the sustainability issues is given here, considering likely changes. However, it is unclear as to how the price of some issues such as waste production, water pollution or inconvenience will change. Present-time estimate is used for such issues, assuming no significant change over the time.

Emissions

Carbon tax. Carbon tax scheme in Australia was in action with a fixed rate of about $25 per ton of carbon (Australian Government, 2011). Although it was repealed in 2014, it is likely to be re-established (Steen, 2005). The unit cost is estimated to reach $150-$500 by 2050, averaged at $260 per ton of carbon (Ackerman and Stanton, 2012).

Damage cost. The economic impacts and social damage costs are predicted to be enormous even with rapid reduction in emissions, ranging between $50 and $1500 (Ackerman and Stanton, 2012), with an average of $530 per ton of carbon in 2050 (Clarkson and Deyes, 2002).

Solid Waste Production

Waste treatment cost. A landfill gate fee of $120-180/ton of waste is charged in Sydney, which is significantly higher than waste recycling or reuse fee; hence people would not choose disposal (Hyder Consulting, 2011). The fee charged for reprocessing of concrete waste is $0-11/ton (Hyder Consulting, 2011). Steel and rock wastes are typically reused, in landscaping for example, with no salvage value. However, cost of collection and transport (approximated to be $50±20/ton) is included in reuse and recycling fees.

Water pollution

Remediation cost. Sediments remediation can be done by dredging, capping or in-place treatment. The former is commonly used for sediments of low chemical concentrations (Rosengard et al., 2010). The unit cost of hydraulic dredging and landfill disposal is approximately $220/$m^3$ of sediment (Mohan et al., 2011). This may however range between $15 and $3300 per m^3 of sediment depending on the type of particles and dredging process (Rosengard et al., 2010).

Worker employment

Contribution to society. The value of employment can be characterized by worker's contribution to economy less cost of employment creation (Dinwiddy and Teal, 1992; Sah and Stiglitz, 1985). Worker's contribution is estimated to be $75 per hour worked (Pye, 2012), with projected growth rate of 1.5±0.1% per annum (Commonwealth of Australia, 2015). Employment cost equals worker's earnings that is about $40 per hour plus an extra 40% to account for superannuation, employer taxes and workers' compensation (ABS, 2019). The earnings are projected to grow at an annual rate of 1.4±0.1% (Commonwealth of Australia, 2015).

Comfort value. The employment value can be seen as the money which maintains people's welfare at level they would enjoy without job; this equals minimum wage they would accept minus unemployment compensation (Londero and Cervini, 2003). Minimum wage is assumed to be 56% of average earnings estimated earlier (Commonwealth of Australia, 2014). So-called 'Newstart Allowance' paid to an unemployed person is $6.5 per equivalent hour worked (Department of Human Services, 2019). The government's spending on the allowance is projected to decline, reaching $5.5±0.5/h in 2050 (Commonwealth of Australia, 2015).

Safety incidents

Insurance value. Social liabilities for safety incidents can be costed using insurance premium paid for employed workers (de Beer and Friend, 2006; Leopold and Leonard, 1987). The insurance premium is estimated to be 3.1% of wages – the wage rate of $40/h for construction workers gives a premium of $1.25/h (ABS, 2019), which is assumed to grow at an annual rate of 1.4±0.1% (Commonwealth of Australia, 2015).

Loss of contribution. Social damages due to injury can be costed using the lost earnings plus the uninsured costs of treatment. Assuming 33 injuries per million working hours and average recovery time of 34 h per work-related injury (Safe Work Australia, 2012), gives 0.11% loss of working hours due to injury. Average earnings of $40/h (ABS, 2019) leads to lost earnings of $0.05/h. Uninsured cost of treatment is assumed to be a fifth of insurance value estimated above (Leopold and Leonard, 1987), giving $0.25/h. These lead to a total unit cost of $0.3/h for safety incidents, which is assumed to follow wages growth at an annual rate of 1.4±0.1%.

Health

Loss of productivity. Depending on people's sensitivity to noise and type of task they do, the reduction in productivity may be between 1.5% and 40% for noise levels just above 80 dB (Safe Work Australia, 2010). Average earnings of $30/h leads to lost earnings of $0.5-12.0 per exposure hour due to reduced productivity. This is also assumed to follow wages growth rate.

Inconvenience

Delay cost. Inconvenience of traffic disruption to commuting people can be costed using lost earnings due to delay (Gilchrist and Allouche, 2005). As given above, average earnings of $30/h is assumed, with an annual growth rate of 1.4±0.1%.

Replacement cost. The inconvenience can also be monetized using the cost of making a detour, as a replacement for blocked access road (Gilchrist and Allouche, 2005). This comprises the rental cost of traffic signs, $4-8 per day, and traffic barriers, $20-40 per day (quoted from Coateshire). Thus, the replacement cost would range between $24 and $48 per day.

Table 4 summarizes the estimates of unit prices and reliability weights for all the intangibles. The lower reliability weights indicate larger variances in the estimates of the associated SEC method. Apparently, these methods have lower influence on the costing outputs.

Table 4 Case example: unit price estimates and reliability weights

Sustainability issue	SEC methods	Units price			Reliability weight
		o	m	p	
Emissions* ($/ton CO2-e)	Carbon tax*	150	260	500	0.94
	Damage cost	50	530	1500	0.06
Solid wastes production* ($/t)	Waste treatment cost*				
Rocks	*Reuse*	30	50	70	1.00
Concrete – fresh	*Recycle*	30	55.5	81	1.00
Steel	*Reuse*	30	50	70	1.00
Water pollution ($/m^3)	Remediation cost	15	220	3300	1.00
Worker employment ($/h)	Contribution to society	30.3	31.0	31.6	0.18
	Comfort value	27.6	27.9	28.2	0.82
Safety incidents* ($/h)	Insurance value*	1.82	1.86	1.91	0.05
	Loss of contribution*	0.44	0.45	0.46	0.95
Heath (noise) ($/h)	Loss of productivity	0.7	9.3	18.3	1.00
Inconvenience*	Delay cost ($/h)	43.7	44.7	45.8	0.13
	Replacement cost* ($/day)	24.0	36.0	48.0	0.87

Investor viewpoint analysis only looks at *
o: optimistic / m: most-likely / p: pessimistic

4.3 Results and Discussion

Having the differences in social and environmental inventory flows and using the shadow price estimates, the monetary flows can be calculated. Table 5 illustrates the differences in the monetary flows associated with sustainability issues between the A and NA forms, at times 0 and T. Since there is no uncertainty associated with present-time estimating, the deterministic dollar values (with no variances) are given at time 0. While, probabilistic estimates (with expected values, E[ ], and variances, Var[ ]) are made for future time T. Also, the worker employment benefits are illustrated using negative values, since the positive values represent the sustainability issues/costs.

Table 5 Case example: differences in monetary flows between A and NA forms, at times 0 and T

Sustainability issue and SEC method	At k = 0		At k = T					
	A-NA		A			NA		
	Quantity	$ value	Quantity	$ value		Quantity	$ value	
				E[ ]	Var[ ]		E[ ]	Var[ ]
Emissions (t CO2-e)								
*Carbon tax**	20.2	505	19.0	5,352	1.2e6	51.1	14,393	1.4e7
Damage cost			19.0	11,622	2.1e7	51.1	31,256	1.6e8
Solid wastes production (t)								
*Rocks (reuse)**	27.2	1,360	44.0	2,200	8.6e4	164.8	8,240	2.9e6
*Concrete (recycle)**	1.8	100	1.4	78	141.6	32	178	1.3e3
*Steel (reuse)**	0.3	15	0.2	10	1.8	0.5	25	23.4
Water pollution (m^3)	0.014	3	0	0	0	0.064	45	1.2e3
Worker employment (h)								
Contribution to society	213	-4,047	507	-15,709	1.2e4	1,362	-42,199	2.1e7
Comfort value			507	-14,145	2.6e3	1,362	-38,000	1.7e7
Safety incidents (worked, h)								
*Insurance value**			507	944	57.8	1,362	2,536	7.8e4
*Loss of contribution**	213	64	507	228	2.9	1,362	613	4.5e3
Heath (noise exposure, h)	626	3,913	5,902	55,282	3.0e8	18,310	171,504	3.0e9
Inconvenience								
Traffic delay (h)	310	-	512	22,895	3.2e4	1,884	84,246	1.1e8
*Road replacement (day)**	8	228	13	468	2.7e3	44	1,584	9.0e4

Investor viewpoint analysis only looks at *

Having the moments and reliability weights associated with different SEC methods, the resultant moments are obtained for each intangible using the formulation given in Section 3.3. Table 6 summarizes the expected values and variances of intangibles' costs, estimated from public and investor viewpoints. From the public viewpoint, health, emissions and worker employment with the largest expected values and variances have the greatest effect on the analysis outputs. The health and emissions issues work in favor of the A form, while the worker employment (with negative expected value) is reversing the decision in favor of the NA form. However, the large variance for worker employment still works in favor of the A form, since it leads to a larger variance of the total present worth. From investor viewpoint, emissions with the largest expected value and variance have the most significant impact on the outcomes.

Table 6 Case example: moments of intangibles' costs for A and NA forms at k = T, from public and investor viewpoints.

Sustainability issue	A		NA	
	E[ ]	Var[ ]	E[ ]	Var[ ]
Public viewpoint				
Emissions	5,697	1.2e6	15,322	1.3e7
Solid waste production	2,288	9.4e4	8,443	3.0e6
Water pollution	0	0	45	1.2e3
Worker employment	-14,420	2.1e3	-38,737	1.2e7
Safety incidents	262	2.7	703	4.3e3
Health	55,282	3.0e8	171,504	3.0e9
Inconvenience	3,384	2.6e3	12,330	2.0e6
Investor viewpoint				
Emissions	5,352	1.2e6	14,393	1.4e7
Solid waste production	2,288	9.4e4	8,443	3.0e6
Safety incidents	262	2.7	703.38	4.3e3
Inconvenience	468	2.7e3	1,584	9.0e4

Estimates of social and environmental monetary flows from public viewpoint, give the following:

$E[NA_{T,SE}] = \$169.6k$, $Var[NA_T] = (\$65.5k)^2$

$E[A_{T,SE}] = \$52.5k$, $Var[A_T] = (\$18.8k)^2$

And investor viewpoint gives the following:

$E[NA_{T,SE}] = \$25.1k$, $Var[NA_T] = (\$5.9k)^2$

$E[A_{T,SE}] = \$8.4k$, $Var[A_T] = (\$1.5k)^2$

Estimates of financial cash flows give the following moments:

$E[NA_{T,F}] = \$297.9k$, $Var[NA_{T,F}] = (\$24.8k)^2$

$E[A_{T,F}] = \$102.8k$, $Var[A_{T,F}] = (\$8.6k)^2$

Combining the moments of social, environmental and financial cash flows gives the moments of net cash flow at T, which is discounted to time 0 giving the moments of total PW and adaptability value. Figures 3 and 4 show the change in adaptability value with r and T, and compare the results of only-financial analysis with those of sustainability analyses from public and investor (or council) viewpoints. The initial cost of building in adaptability is estimated to be \$57.7k; inclusion of monetized social/environmental issues slightly increases this figure to \$60.0k for both sustainability analyses.

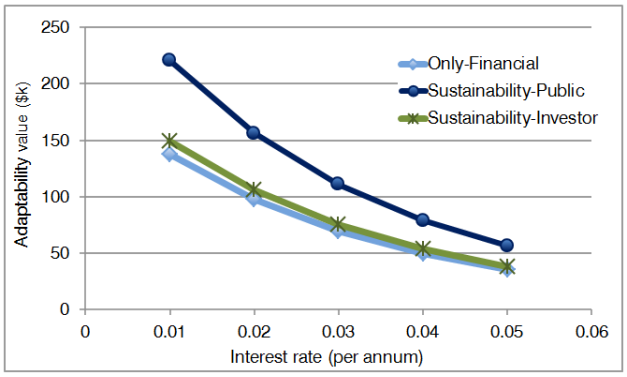

Figure 3 Case example – change in adaptability value with interest rate, T = 35 years

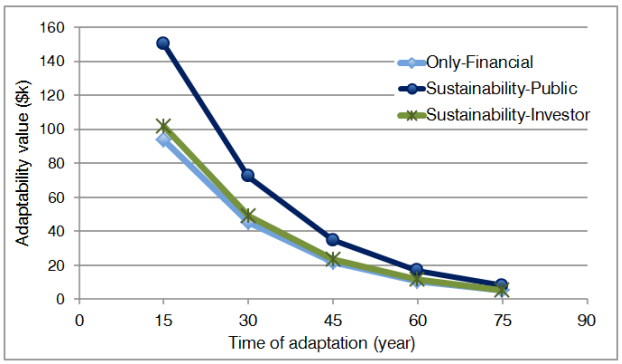

Figure 4 Case example – change in adaptability value with time of adaptation T, r = 5% p.a.

It is seen, from both viewpoints, that building in adaptability is more viable for lower r and lower T. Compared to only-financial analysis, the sustainability analysis from public viewpoint significantly improves the viability of seawalls adaptability. The improvement is manifested in maintaining viability for longer adaptation times (changed from just below 30 years to above 35 years) or greater interest rates (changed from 3.5% p.a. to 5% p.a.). This is mainly due to incorporating health, emissions, and worker employment issues in the analysis. However from investor viewpoint, neither the initial cost nor the adaptability value changes considerably by inclusion of social and environmental costs. Hence, there is not much potential for encouraging the councils in investing in seawalls adaptability; even though, such potential may be developed in future should pricing regulations be set in the market for intangibles such as worker employment, health issues and inconvenience due to traffic disruption.

The analysis attempted to capture the increasing sustainability imperatives and uncertainties over the time; however, the future changes in unit price of some sustainability issues such as waste production or water pollution were unclear and excluded. Much larger uncertainties could be assumed leading to greater adaptability values. Also, inclusion of environmental costs associated with resource depletion, namely materials consumption and energy use, could further improve the viability of the specific designed-in adaptability in the case example. Including such sustainability intangibles in the analysis requires developing monetization methods. Future studies can be targeted towards addressing the above issues.

5. Conclusion

The paper presented an approach for incorporating sustainability in ROA to value designed-in adaptability of infrastructure. This was realized by integration of social and environmental costing with an options analysis that is suitable for engineering applications. The paper suggested looking at sustainability from public and investor viewpoints to examine the potential for encouraging investment in adaptability. The method was demonstrated on a seawall case example under changing climate effects. It was shown, for the assumptions considered, that

inclusion of sustainability issues improves the viability of designing in adaptability. However, no general conclusion can be drawn on the viability of designed-in adaptable infrastructure, and each situation requires an individual analysis. Designing in adaptability will be more sustainable in some situations, but not necessarily in all situations. The methodology will be the same for all situations, but the assumptions about design and estimation may change.

ROA used in the literature for financial valuation of investing in adaptable infrastructure; social and environmental aspects not addressed unless using inadequate methods. The paper advances current literature by incorporating sustainability into ROA; this specifies whether and to what extent inclusion of sustainability issues may improve the viability of designed-in adaptability.

The paper's valuation approach resulting in a quantitative measure for sustainability of adaptable infrastructure is original. The outcomes will be useful to construction industry practitioners, investors and corporates with social or environmental liabilities, contemplating measuring sustainability for decision making on building in adaptability.

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Assessing the Seamlessness of Bangkok Metropolitan Public Transport by using Modified Quantitative Gap Analysis

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ABSTRACT

A sustainable transportation system requires a larger contribution to public transport share in comparison to private transport. Bangkok Metropolitan, the study area, exhibits a significant transport modal alteration trend towards public transport, in line with the expansion of Bangkok Transit System (BTS) and Mass Rapid Transit (MRT) for more coverage within the metropolis along main roads along with expansion of public bus routes, which increases the seamlessness and reduces transit time. This study is important as we believe that the higher seamlessness the more urban travelers would shift to using public transport modes. This matter is considered as a pertinent urban transport problem. This study aims at understanding the level of transit seamlessness of the Bangkok public transport system. The study was carried out by firstly measuring six factors of the regular transit process, on formal and informal transport modes used by Bangkokians. These six factors were observed along the origin and the destination of the travelers with respect to travel time, number of transit points, average transit time, comfort, and transit facilities including facilities for disables, and walking distance. A total number of 300 public transport users were selected as respondents, 50 respondents for each selected transit hub. The selection was based on convenient random sampling considering the variability of destinations and purpose of travel. Despite a different destination, the residence was set as the origin. By using Modified Quantitative Gap Analysis, based on six selected transit hubs, the study found that the seamlessness of the inter-modal transits in Bangkok exhibits a characteristics of hard transit process, particularly for disabled people, notwithstanding the continuous efforts to make the seamless transit are in place, particularly with respect to infrastructure facilities.

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1. Introduction

Sustainable transportation system becomes a common ultimate goal of many cities in managing their urban transport to serve the citizens (Schiller & Kenworthy, 2017), as it is claimed to possess the elements of sustainability based on sustainability indicators (Haghshenas & Vaziri, 2012). Haghshenas & Vaziri (2012) also asserted that the problem of urban mobility and environmental impacts are today's major issues in the metropolis in the world. This is a critical barrier in accomplishing sustainable urban development. Since one of the objectives of sustainable transportation is coping with the air pollution stems from the transport sector (McCormick, et al., 2013), sustainable urban development and sustainable transport are, therefore, shared common issues towards sustainable development.

Seamless transit process is one of the essential components of a sustainable urban transportation system (Loo & du Verle, 2017; Haque, Chin & Debnath, 2013). A seamless transit is an easy and smooth intermodal transfer experienced by urban travelers, which has a potential power to attract more public transport users and pedestrians, and thus promoting sustainable urban transportation from the way it reduces per capita emission stems from urban transportation and promotes welfare in the society. The increased share of public transport over private transport may lead to strategic multiplier effects towards sustainable transportation system (Litman, 2015). A transportation system is said to be sustainable when the environmental impacts i.e. noise, air pollution due to emission, and waste generated by the system are within the acceptable limit. The system should have no or trivial impacts on climate change. Moreover, the transportation system should bring economic growth to the city and societies and promote citizens welfare through widening access and equity for the whole citizens (Carmon & Fainstein, Eds., 2013). With this broad vision of sustainable transportation, Kamargianni et al., (2016) argue that the seamless transit does not directly contribute to a sustainable transportation system, rather indirectly but strongly support the elements of sustainable development, in a way that greater contribution of public transport would reduce emission and transport energy and therefore reducing greenhouse gas emission, reducing environmental impacts and climate change.

The transit system in Bangkok Metropolitan involves formal and informal transport modes. Formal transport mode in this regards is any mode of transport, which are formally recognized by the authority and legally formalized. Informal transport mode, on the other hand, is may be recognized by the authority but does not legally formalize by law. Günther & Launov (2012) and Pugh (2013) asserted that cities in developing countries are a predominant harbor of the informal sector for one strong reason which is the characteristics of the informal sector is perfectly compatible with the conditions of developing countries. In Bangkok Metropolitan, there are basically nine or ten formal and informal transport modes. The seamlessness of the intermodal transit in Bangkok Metropolitan seems an essential issue to be solved to attract more public transport users. This study attempts to understand this issue. A casual survey by the authors shows that transit process in most available hubs in Bangkok is a thoughtful issue to be pondered by public transport authorities in Bangkok.

Table 1 exhibits samples of intermodal transit variables acquired in a pre-research survey by authors.

Table 1 Seamlessness Intermodal Transit Variables at selected hubs measured during pre-research survey

Aspect	Chatuchak	Victory Monument	Asoke
Transit time (min)	6-13	3-18	5-11
Transit distance (m)	15-75	5-125	20-110
Level of crowdedness	Heavy	Heavy	Loose
Existing transit facility	Escalator, elevator, bridge, underground metromall	Escalator, pedestrian bridge	Escalator, elevator, pedestrian bridge, underground metromall
Idiosyncratic Quality of transit	Uneasy particularly for disabled person	Uneasy particularly for disabled person	Uneasy particularly for disabled person

A brief description of these public transport modes in Bangkok is given in the following section, and their illustrations are given in Figure 1.

2. Formal and Informal Public Transport Modes in Bangkok

The general characteristics of the public transport users in Bangkok are shown in Table 2.

Table 2 General Characteristics of Public Transport Users in Bangkok

Attribute	Variables	Percentage
Age Group (year)	5-15	2
	16-20	5
	21-30	25
	31-40	38
	41-50	18
	>50	12
Gender	Male	43
	Female	57
Income Group (THB/month)	=<15,000	58
	15,001-30,000	33
	30,001-50,000	5
	>50,000	4
Education Level	High school and below	61
	University	32
	Others	7

Table 2 shows that the public transport users are predominantly the lower income group. It is understood that the higher income group are mostly the private transport users that actually contributes to the traffic congestion in many parts of Bangkok. This is challenge for the transport planners and authorities to

voluntarily drive the higher income group to shift to public transport, and at the same time, the improvement of public transport system in Bangkok is continuously carried out. It seems that the public transport network in Bangkok is being expanded to the neighboring province around Bangkok within Bangkok Metropolitan Region.

2.1 Rail-based Transportation Systems

The Bangkok Mass Transit System (BTS) or BTS Sky Train is the primary public transport in Bangkok. It is an elevated rail-based transportation system operated by BTS Group Holding Public Company Limited, covering 52 km of an elevated railway connecting 43 stations, and commenced in operation since 5 December 1999. The present daily ridership of BTS is about 650,000 passengers. It is consistently increasing since the beginning of the operation (BTS Skytrain, 2019). Metropolitan Rapid Transit (MRT) is an underground rail-based mass transportation system, with a total length of 45 km, operated by Bangkok Expressway and Metro Public Company Limited (BEM) under a concession granted by Mass Rapid Authority of Thailand as the owner of MRT lines. MRT was commenced on 3 July 2004 (MRTA, 2019). Airport Link is an elevated railway on a viaduct over on the main eastern railway, with line length is 28.7 km, operated by the consortium group of Charoen Pokphand Holding (CP), Ch. Karnchang PLC. (CK), Bangkok Expressway and Metro PLC. (BEM), Italian-Thai Development PLC. (ITD) and China Railway Construction Corporation Limited (CRCC). The owner is the State Railway of Thailand (SRT). It started in operation since 23 August 2010 (Airport Rail Link, 2019). The State Railway of Thailand also runs Eastern and Northern Lines which connects Bangkok Railway Station (Hualamphong) and some cities surrounding Bangkok Metropolitan, through some railway stations within Bangkok Metropolitan.

2.2 Non-rail Transportation System

Public Bus Transport: Various public buses are operating in 198 routes across the Bangkok Metropolitan Region which consists of Bangkok Metropolitan plus five adjacent provinces Nakhon Pathom, Pathumthani, Nonthaburi, Samut Prakan and Samut Sakhon (Bangkok Bus Routes, 2019; Wikipedia, 2019). They are basically belonging to two types: air conditioning and non-air conditioning buses. The bus fare varies according to distance and type of bus. The total length of bus routes in Bangkok Metropolitan Region is estimated about 4,950 kilometers with a total number of vehicle-kilometer travel in a year is predicted around 213,840,000, and the estimated person-kilometer traveled is about 4,276,800,000 annually. Despite no data to prove the contribution of public bus transport in Bangkok Metropolitan, its role is expected significant in comparison to other modes of transport.

Water Transport (Boat): Water transports in Bangkok Metropolitan are mostly on Chaopraya River, the main river in Bangkok, and small rivers (khlongs) within Bangkok. The fare of small river boat is between 10-30 baht depending on the distance. The fare of the boat in Chaopraya river is 15 baht flat rate. The first pier of water transport in Chaopraya river is started in the downstream at Wat Rajsingkorn, Bangkolaem, and go to the upstream as far as Nonthaburi, with a distance of 20 km. Meanwhile, for the small river transport in khlongs, the length of the line is about 120 km including the rivers transport for tourism purposes. The estimated person-kilometer traveled of water transport in Bangkok Metropolitan is about 70,560,000 annually. One of the advantages of using water transport in Bangkok is traffic jam free with reasonably low fare. However, the route is limited to the only area with suitable khlongs. The khlongs are normally maintenance-free since all the water depths in the khlongs are naturally maintained by sea level, and the erosion is small and controlled, thus the water depth is relatively stable for the whole year long.

Vans: There is the 10-seat capacity of van commuters from surrounding provinces to Bangkok and vice versa or within Bangkok itself. The fare is between 20-40 baht depending on the distance. However, for long distance vans, for instance, Bangkok-Pattaya or Bangkok Huahin, the fare is between 200-400 baht. The person-kilometer traveled of the commuter van is estimated of about 115,200,000 per year.

Taxi: This private-like public transport is the most obvious mode of transport in the cities including Bangkok Metropolitan because of flexible route and time as well as its convenience. The fare is certainly counted based on the distance. The estimated person-kilometer traveled by Bangkok taxi is about 7,560,000,000 annually. This is certainly the largest contribution to public transport in Bangkok.

Tuk-tuk (another type of taxi): Tuk-tuk is another type of taxi and only available in Bangkok. This three-wheeled taxi can accommodate 3 passengers, with flexible routes and time. The fare is depending on the distance. The estimated person-kilometer traveled by tuk-tuk is about 388,500,000 annually.

Songteaw (Pickup): This kind of transport is normally operated only in the city periphery where other formal transport modes do not reach this area. Songtaew can accommodate 14 passengers in two rows. The fare depends on the distance and the longest route is about 30 km. The estimated person-kilometer traveled by Songtaew is 100,800,000 per year.

Motorsai Krabchang (Motorbike Taxi): This is the most ubiquitous transport modes in Bangkok for their existence in many places in Bangkok, particularly near the bus stops, the mouth of alleys (sois). Their present makes public transportation in Bangkok is almost door-to-door transport service. Because of this overlap feature, it sometimes creates conflict among the drivers. The motorbike taxi normally serves only short distance travel e.g. 5 km maximum. The fare is between 20-80 baht depending on the distance. This is a traffic jam free taxi as motorbike is able to dodge the jam. The motorbike taxi can only accommodate 1 passenger per travel. The total estimated person-kilometer traveled in Bangkok is about 1,670,400,000 annually.

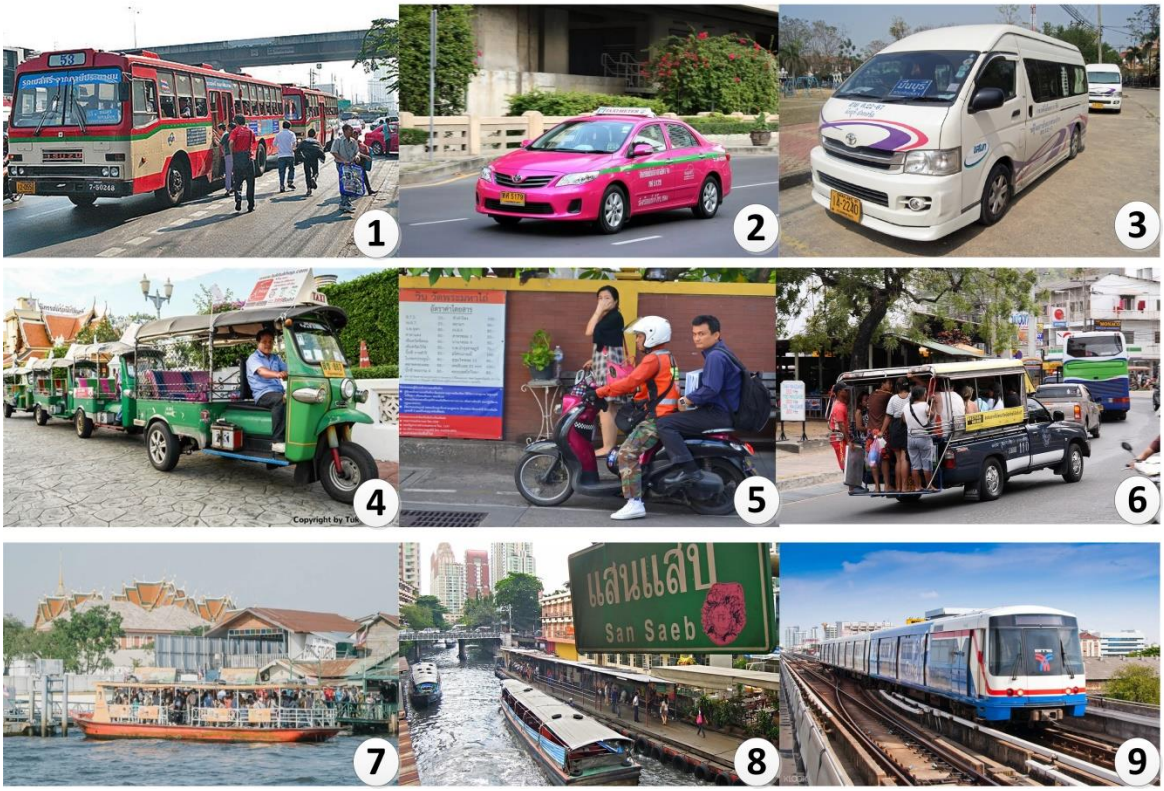

Figure 1: Various Types of Public Transport in Bangkok
[Note: (1) Bus (2) Taxi (3) Van (4) Tuktuk (5) Motorbike Taxi (6) Songtheaw (7) River Boat Chaopraya (8) Khlong Boat (9) BTS]

The above public transport modes in Bangkok are basically formal and informal public transport, which, in this study, their individual function will be assessed to deliver the transit process of the citizens in accomplishing their trip i.e. from origin to destination. Based on a study by Permana et al., (2018) and Permana et al., (2015), the characteristics of formal and informal transport are shown in Table 3.

Table 3 Formal and Informal Public Transports Characteristic

Aspect	Formal Public Transport	Semi-formal and Informal Public Transport
Service Delivery	Designated, fixed and personalized routes	Personalized routes, adaptive
Schedule	Semi-fixed, passenger-driven	Flexible, passenger-driven
Reliability of service	Inconsistent to reliable depending on the type	Inconsistent to semi-reliable
Vehicle Capacity	4-seat to 500-seat passengers	2-seat passengers
Vehicle Type	Motorized	Motorized and non-motorized
Ownership	Public and Private	Private, individual
Market Perspective	Monopolist (public), Entrepreneurial (private)	Entrepreneurial, individual
Labor	Semi-skilled	Semi- to non-skilled labor
Organization	Bureaucracy, route associations	Individual, social associations
User's social status	Low to medium income	Low to medium income
Fare structure	Fixed, standardized	Variable, non-standardized

Source: AS Permana et al., (2018)

In the case of formal, semi-formal, and informal public transports in Bangkok, the characteristics are almost the same as what is described in Table 3. By their respective features and advantages, along with transit infrastructure in Bangkok that connects these nine or ten transport modes, their seamlessness will be assessed by using the Modified Quantitative Gap Analysis (MQGA). The MQGA is used to evaluate the degree of importance of the

elements of transit infrastructure, because of its suitability for assessing the gaps while avoiding subjective views.

3. The seamlessness of the Transit Process

Bangkok public transportation system has a potential feature to offer a seamless transit system (Chalermpong et al., 2018). A seamless transit system, in this case, is defined as a process of an intermodal transfer undertaken by either able or disable person without experiencing difficulties in accomplishing travel from origin to destination. While at a macro level a seamless transit requires the integration of the system for all transport modes, the users understand how to use it, standardization of fares for all transport modes that makes easy and comfortable for the travelers, and an integrated transit hub, at micro level it needs an easy and comfortable transfer pathways, shortest possible transit distance and transit time, accessible by either able or disable person, and availability of additional convenient facilities within the premise. A more detailed explanation of the micro level requirements of a seamless transit in case of Bangkok public transportation system is given in the subsequent section.

Integrated Transit Hub: The smooth interconnection of intermodal transport is a prerequisite of an integrated transit. The hub must be a point where some transport modes are connected, and make the interchange between transport modes by the travelers are possible, easy and comfortable. The interchange is preferably horizontal. However, if the horizontal interchange causes expanding hub, and this makes transit distance or transit time larger, a vertical interchange is then preferred, with a condition that accessibility by disabled persons must be in place. Combination of horizontal and vertical interchange most of the time cannot be avoided.

Easy and Comfortable Transfer Pathways: Easy transfer pathway determines the success of seamless transit. The travelers will have convenient experience in the transit process for their journeys. In a comfortable transfer, the pathways must be protected from sunlight and rainfall or other weather elements, to provide maximum comfort for the travelers. The pathways of intermodal transfer must be accessible by all including disables, elderly people, and disadvantages.

Transit Distance and Time: A transfer distance between transport modes must be as short as possible. This is to ensure an easy, comfort and in-time intermodal transfer for all types of travelers. The transfer process can be done as convenient as possible by travelers. Shorter transfer distance may minimize uncontrolled crowd during rush hours. With well-informed travelers about the hub, uncontrolled crowd with possible unwanted effect can be minimized.

Convenient Facilities: Various facilities within the premise of transit hubs such as convenient stores, information desk, ticket vending machines, toilets, and other facilities would make the transit experience more exciting. The consequence of these facilities is that the hub must be sufficiently large, which is to some extent, difficult to provide unless underground.

The above requirements will be tested in selected transit hubs of formal transport modes i.e. BTS, MRT, Public Bus, Taxi and Private Transport; and informal transport modes i.e. motorbike taxi. The selected transit hubs are shown in Table 4. The selection of hubs is based on the number of transportation modes meet in the hubs. The only hub with more than three primary transport modes has been selected. An Analytic Hierarchy Process method is used to analyze the seamlessness, and the users' perception is employed to evaluate the degree of seamlessness based on their experience.

Table 4 Selected Transit Hubs

No	Hub	Intermodal Transport
1	Mochit-Chatuchak Park	BTS, MRT, Public Bus, Taxi, Motorbike Taxi
2	Phayathai	BTS, ARL, SRTET, Public Bus, Taxi, Motorbike Taxi
3	Makkasan-Petchburi	MRT, ARL, SRTET, Public Bus, Taxi, Motorbike Taxi
4	Sukhumvit-Asoke	MRT, BTS, Public Bus, Taxi, Motorbike Taxi
5	Saladaeng-Silom	MRT, BTS, Public Bus, Taxi, Motorbike Taxi
6	Saphan Taksin-Sathorn	BTS, River Boat, Public Bus, Taxi, Motorbike Taxi, Songteaw

Six transit hubs were selected among 17 possible hubs to cover as much as a possible number of formal, semi-formal, and informal transport modes. The selected hubs are shown in Figure 2. The features of each hub are explained in the subsequent sections.

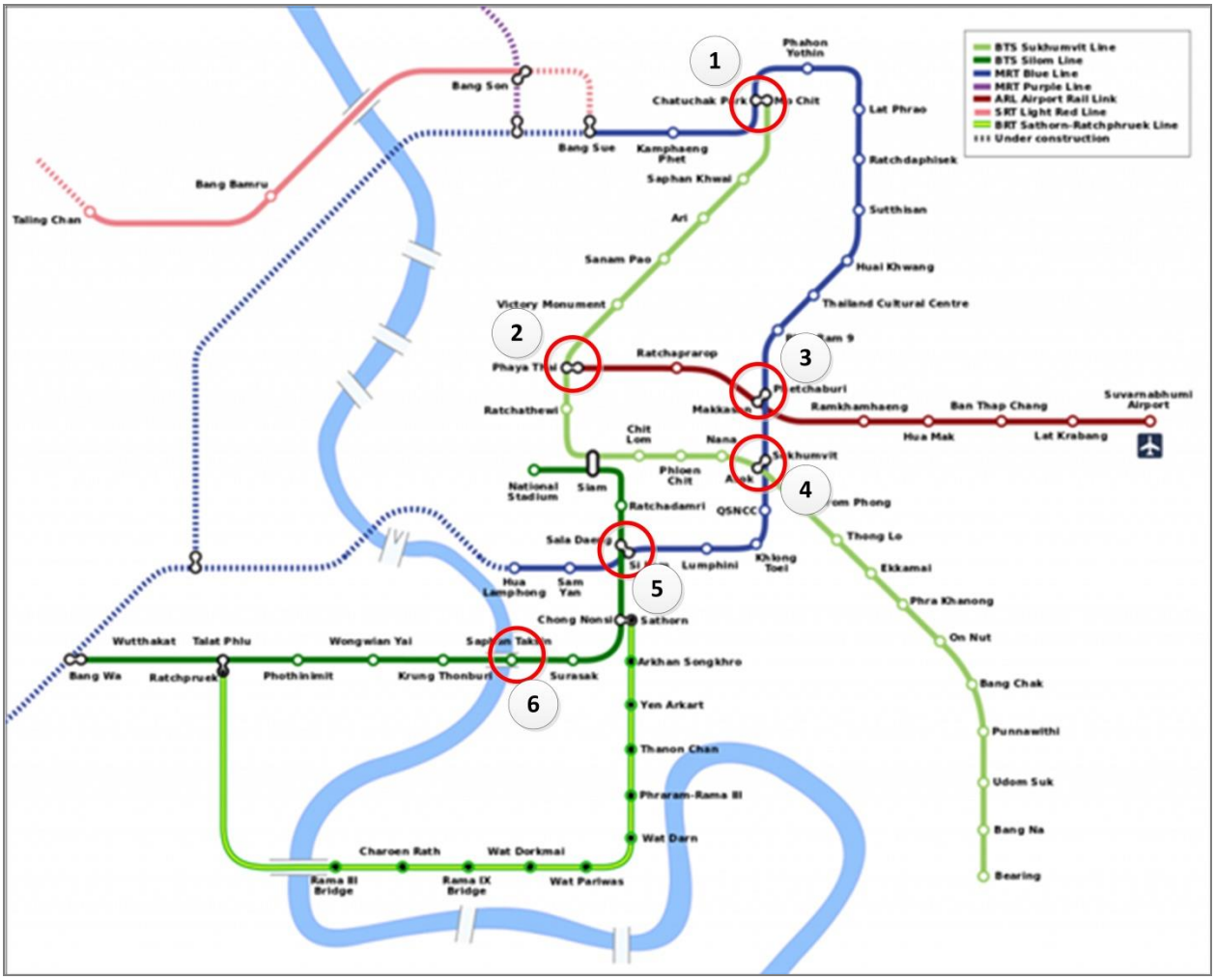

Figure 2 Selected Transit Hubs in Bangkok

4. Selected Transit Hubs

Among 17 transit hubs within Bangkok Metropolitan, which are qualified for assessment, 6 transit hubs have been selected for assessment as shown in Table 2. During the course of discussion in this section, there is a rating system proposed by the authors on the six variables of the intermodal transit, based on the perceptions of the transit hub users. These variables include integration of the transit, easiness of the transit process, comfort during the transit, transit distance, transit time, and convenient facilities. The scales of these variables are ranging from 1 (worse) to 5 (excellent), with the following explanation:

For the qualitative arguments such as integration of the transit, easiness of the transit process, comfort during the transit, and convenient facilities, the transit hub and public transport users, the standardized perception of the users is applied, which is $\mu+2\sigma$ is calculated as excellent (5) and $\mu-2\sigma$ as worse (1), and μ itself is treated as neutral (3). Then based on these values, the rating is given.

For quantitative argument such as transit distance and transit time, the following discrete values are applied:

- The score is 5 (Excellent) if distance 0-25 meters, or transit time 0-1 minutes
- The score is 4, if distance: 26-50 meters, and t: 1-2 minutes
- The score is 3, if distance: 51-100 meters, and t:2-5 minutes
- The score is 2, if distance: 101-200 meters, and t:5-10 minutes
- The score is 1 (worse), if distance: >200 meters, and t>10 minutes.

There is, of course, no definite formula to determine these subjective arguments, but the most important message of this rating is that the reader would be able to imagine either the easiness or difficulty in undertaking the transit process, without necessary to carry out the transit by their own.

4.1 Chatuchak-Mochit Transit Hub

Physical Feature: Chatuchak and Mochit transit hub is considered as one of the largest hubs in Bangkok as Bangkok Mass Transit System (BTS) – the Skytrain, Bangkok Mass Rapid Transit (MRT), Bus, Taxi, Van, Motorbike Taxi, and private cars (Park and Ride at Mochit) are jointly forming a transit hub in this area. In the future, the State Railway of Thailand Northern Track (SRTNT) will also join the hub, although the connection is a little bit farther than 500 meters. The interconnection in the Chatuchak-Mochit hub is graphically shown in Figure 3.

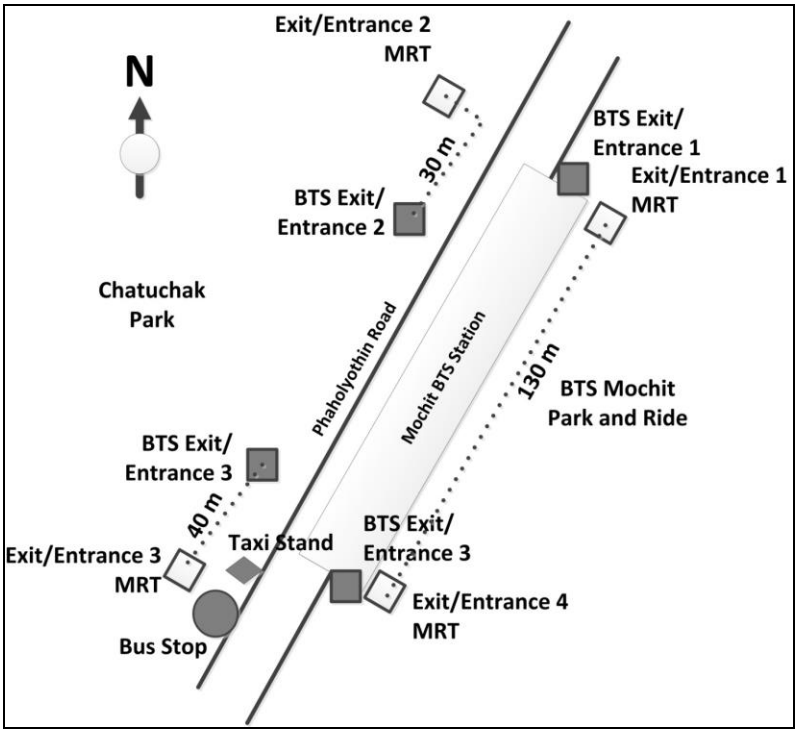

Figure 3 Mochit-Chatuchak Hub
(Transport Modes: BTS, MRT, Bus, Taxi, Motorbike Taxi, Park and Ride)

From the observation in all MRT stations, the facilities for in and out of disabled people from the very first entrance up until entering the train, the disabled people will be able to travel independently i.e. without the bits of help from others by using MRT. The elevator, which is provided a convenient ramp, is available through ticketing service and the entrance of the train. A different situation exists in the BTS stations. Only a few BTS stations are provided an elevator for disable person. Not to mention the public bus and other transport modes in Bangkok. This condition brings to a situation that public transport in Bangkok is not at all friendly for a disabled person, even though the disabled persons are traveling with the help of others. This fact will be proven by using field observations and opinion from the users.

Transit Process: Time required for transit from MRT (exit from the train) to BTS (entering the train), according to several times survey, in Chatuchak-Mochit transit hub, is in average about 16.5 minutes. This includes the waiting time of the BTS. The pathway within the premise of MRT is comfortable with facilities of Metro Mall, ATM, and food and beverage shops. The signage is seemingly also sufficient to ease where to go. However, this is not for the first time travelers or the ones who do not now the above-ground situation i.e. the locations of the exits. Two to five minutes additional times will be required if one goes out through the wrong exit since each exit was designed for different directions.

The survey results on four qualities of a transit hub namely integration, easy and comfortable transfer pathways, transit distance and time, and, convenient facilities at Chatuchak-Mochit Transit Hub are summarized in Table 5. The surveys were carried out by assessing every possible transit process by the users, particularly in two intermodal transfers, and vice versa. The distance within the premise was approximated by a number of constant steps, since direct measurement by using a measuring device will need special permission and sufficient surveyors. The time is however measured by using stop watch.

Table 5 Summary of the Transit Process Survey in Chatuchak-Mochit Transit Hub

Transit Process	Quantity of Transit	Quality of Transit	Own Rating (1:worse, 5:excellent)
MRT to BTS	• Time required (gate-to-gate): 8 minutes • Vertical Distance: 20m by escalator+10m manual stair • Horizontal Distance: 120m	• Elevator available at MRT • Vertical transport: escalator • Pathways: within MRT: excellent, within BTS: good, in between: bad i.e. uneven surface, crowd • Disable: not possible	Integration: 2 Easiness: 3 Comfort: 3 Transit distance: 3 Transit time: 3 Convenient facilities: 4
BTS to Bus/Taxi/Motorbike Taxi	• Time required: 6 minutes • Vertical distance: 10m stair • Horizontal Distance: 50m	• Elevator available at BTS • Vertical transport: stair • Pathway within BTS: good, in bus platform: bad, crowd, disorder • Disable: not possible	Integration: 2 Easiness: 2 Comfort: 2 Transit distance: 3 Transit time: 3 Convenient facilities: 2
MRT to Bus/Taxi/Motorbike Taxi	• Time required: 8-15 minutes (depending on the exit) • Vertical distance: 20-40m (depending on the exit) • Horizontal Distance: 80-150m (depending on the exit)	• Vertical transport: escalator/elevator • Pathways: within MRT: excellent, pathways to bus/taxi/motorbike stands: bad i.e. uneven surface, crowd • Disable: not possible	Integration: 2 Easiness: 2 Comfort: 2 Transit distance: 3 Transit time: 3 Convenient facilities: 2

4.2 Phayathai Transit Hub

Physical Feature: Phayathai transit hub connects BTS, Airport Rail Link (ARL), State Railway of Thailand Eastern Track (SRTET, which runs from Bangkok to Aranyaprathet), Bus, Taxi, and Motorbike Taxi. An elevator is available in the ARL but unavailable in the BTS. In terms of horizontal distance, the hub offers a within-walking-distance quality, as exhibited by the closeness of ARL Phayathai Station, BTS Phayathai Station, Bus stands, Motorbike stands and Taxi, which the farthest is around 70 meters. The closest transit is between SRTET and bus, which is about 10 meters. One of the main defects of this hub is the presence of rudimentary train station of the SRTET in Phayathai, which is not convenient for the travelers. However, this hub is unfriendly to disabled people. The hub is schematically shown in Figure 4.

The gate of BTS and ARL at Phayathai Hub is practically at the same floor, and it is therefore convenient to transfer in both directions. Transfer from BTS to bus through CP Tower is also close. The only transfer from BTS to south-bound bus is little bit far with about 150 meters away from the BTS exit.

Transit Process: The shortest transit distance in this hub is from SRTET to Bus or Taxi or Motorbike Taxi with just a few meters away. But with respect to comfort, this part does not offer any comfort for the travelers. The most comfortable transit is probably between BTS and ARL vice versa, because of both platform shares the same premise and floor (as exhibited in Figure 5). The most uncomfortable transit happens when a traveler from Suvarnabhumi Airport with luggage who getting-off at Phayathai (the terminal station) to bus or taxi. The possible barriers are bringing the luggage through stair or grabbing the luggage through the uneven surface of pathways after exiting from the BTS or ARL stations. The summary of transit process is given in Table 6.

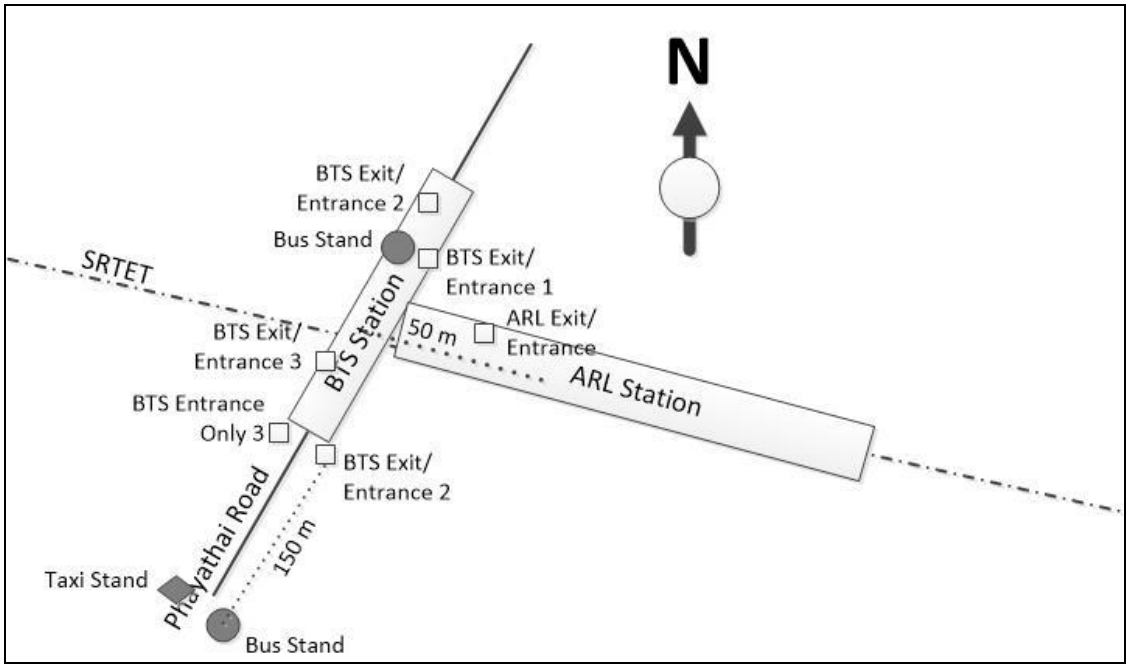

Figure 4 Phayathai Hub
(Transport Modes: BTS, ARL, SRTET, Bus, Taxi, Motorbike Taxi)

Figure 5 Pathway to ARL from BTS at Phayathai

4.3 Makkasan-Petchburi Transit Hub

Physical Feature: The transport modes involved in the transit process in this hub are ARL, SRTET, MRT, Bus, Taxi, and Motorbike Taxi. A 100-meter length of Sky Bridge connects MRT Makkasan ARL station and MRT exit/entrance, and it makes about 150 meters the total distance of both. This hub is not friendly to disable even though MRT and ARL provide elevators, but both are separated by a busy junction, which is impossible to cross by disabled people. On the other hand, the disabled people are not possible to go through the Sky Bridge as the end part of the Sky Bridge at MRT entrance is not equipped with an elevator. The hub is schematically exhibited in Figure 6.

Transit Process: the transit can be done among MRT, ARL, SRTET, Bus, Taxi, and Motorbike Taxi. However, this transit process is, to some extent, neither for disable people nor disadvantages i.e. elderly. However, for certain travel, for example, from any MRT station to the Suvarnabhumi Airport, disabled people will be able to travel alone, by stopping at Asoke station, then exit through the available elevator and connect through Sky Bridge to ARL and continue to the Airport. For any other destinations, the disabled people will not be able to travel alone without helps from any other people. The process of transit is summarized in Table 7.

Table 6 Summary of the Transit Process Survey in Phayathai Transit Hub

Transit Process	Quantity of Transit	Quality of Transit	Own Rating (1:worse, 5:excellent)
MRT to ARL	• Time required (gate-to-gate): 3 minutes • Vertical Distance: 10m by escalator+10m manual stair • Horizontal Distance: 30m	• Elevator available at ARL • Vertical transport: escalator • Pathways: within MRT: good, within ARL: good, in between: good • Disable: not possible	Integration: 4 Easiness: 4 Comfort: 3 Transit distance: 4 Transit time: 4 Convenient facilities: 3
BTS to Bus/Taxi/Motorbike Taxi	• Time required: 3 minutes • Vertical distance: 10m stair • Horizontal Distance: 20m	• Escalator available at BTS (one side, entrance only) • Vertical transport: stair • Pathway within BTS: good, in bus platform: bad, crowd, disorder • Disable: not possible	Integration: 3 Easiness: 2 Comfort: 2 Transit distance: 3 Transit time: 3 Convenient facilities: 3
SRTET to Bus/Taxi/Motorbike Taxi	• Time required: 2 minutes • Vertical distance: 0 • Horizontal Distance: 10m	• Vertical transport: none • Pathways: worse • Disable: not possible	Integration: 3 Easiness: 2 Comfort: 2 Transit distance: 4 Transit time: 4 Convenient facilities: 3

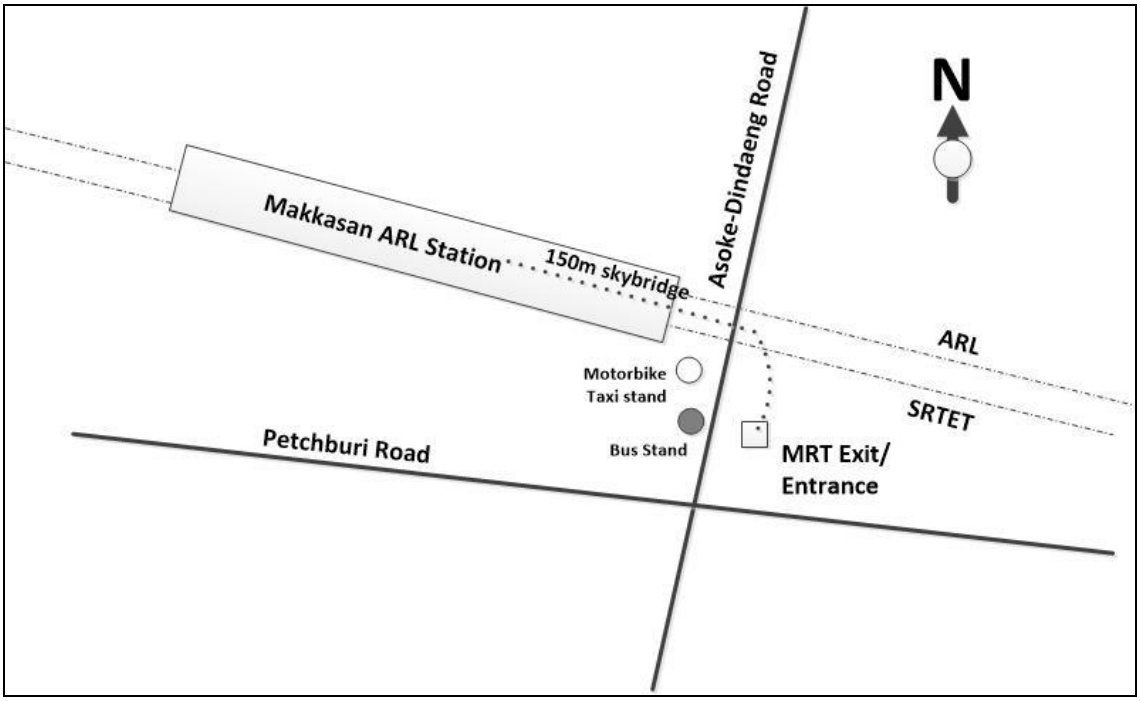

Figure 6 Makkasan-Petchburi Hub
(Transport Modes: ARL, SRTET, MRT, Bus, Taxi, Motorbike Taxi)

Table 7 Summary of the Transit Process Survey in Makkasan-Petchburi Transit Hub

Transit Process	Quantity of Transit	Quality of Transit	Own Rating (1:worse, 5:excellent)
MRT to ARL	• Time required (gate-to-gate): 8 minutes • Vertical Distance: 30m by escalator • Horizontal Distance: 150m	• Elevator available at ARL • Vertical transport: escalator • Pathways: within MRT: good, within ARL: good, in between: good (Sky Bridge) • Disable: not possible	Integration: 3 Easiness: 3 Comfort: 3 Transit distance: 2 Transit time: 2 Convenient facilities: 2
ARL to Bus/Taxi/Motorbike Taxi	• Time required: 5 minutes • Vertical distance: 10m stair • Horizontal Distance: 30m	• Escalator available at ARL (going up only) • Vertical transport: stair • Pathway within ARL: good, in between: busy traffic, bus platform: bad, disorder • Disable: not possible	Integration: 2 Easiness: 1 Comfort: 1 Transit distance: 2 Transit time: 2 Convenient facilities: 2
MRT to Bus/Taxi/Motorbike Taxi/Park and Ride	• Time required: 5 minutes • Vertical distance: 20m by elevator • Horizontal Distance: 20m	• Vertical transport: elevator • Pathways: busy traffic • Disable: not possible	Integration: 1 Easiness: 1 Comfort: 1 Transit distance: 2 Transit time: 2 Convenient facilities: 2

4.4 Sukhumvit-Asoke Transit Hub

Physical Feature: This hub connects BTS, MRT, Bus, Taxi, and Motorbike Taxi. Motorbike taxi is practically available in most of the alley's mouths in Bangkok. This hub provides the same feature with other hubs for disabled people in terms of unfriendliness. MRT, which comes more recent than BTS in Bangkok, provides a friendlier feature for disable persons. The elevator and ramps for in and out of the disabled travelers are in place. However, only a few BTS stations provide facilities for disabled people. The hub is schematically shown in Figure 7.

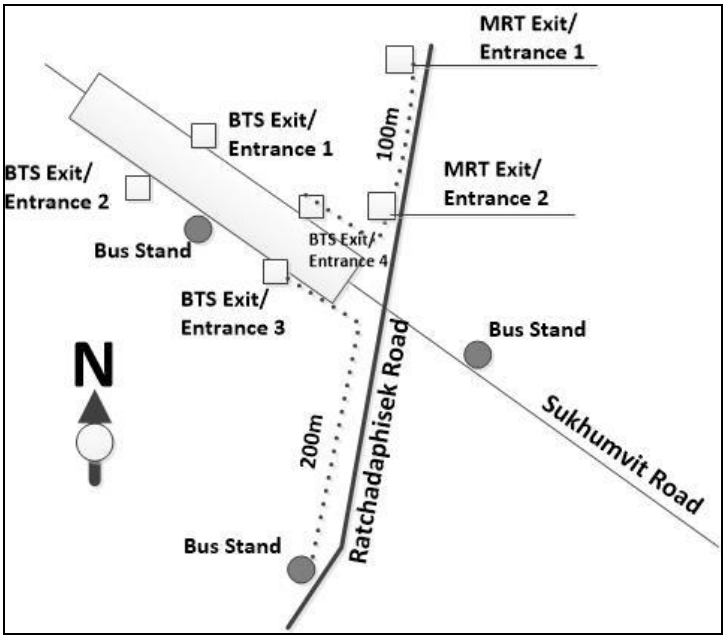

Figure 7 Sukhumvit-Asoke Hub
(Transport Modes: BTS, MRT, Bus, Taxi, Motorbike Taxi)

Table 8 Summary of the Transit Process Survey in Sukhumvit-Asoke Transit Hub

Transit Process	Quantity of Transit	Quality of Transit	Own Rating (1:worse, 5:excellent)
MRT to BTS	• Time required (gate-to-gate): 3 minutes • Vertical Distance: 20m by escalator+10 meter stair • Horizontal Distance: 5m	• Elevator available at MRT • Vertical transport: escalator and stair • Pathways: within MRT: good, within BTS: good, in between: bad • Disable: not possible	Integration: 2 Easiness: 3 Comfort: 2 Transit distance: 3 Transit time: 3 Convenient facilities: 3
BTS to Bus/Taxi/Motorbike Taxi	• Time required: 3 minutes • Vertical distance: 10m stair • Horizontal Distance: 30m	• Vertical transport: stair • Pathway within BTS: good, in between: bad, at platform: bad, disorder • Disable: not possible	Integration: 3 Easiness: 3 Comfort: 2 Transit distance: 3 Transit time: 3 Convenient facilities: 3
MRT to Bus/Taxi/Motorbike Taxi/Park and Ride	• Time required: 5-10 minutes (depending on exit/entrance location) • Vertical distance: 20-30m by elevator and stair (depending on exit/entrance) • Horizontal Distance: 20-80m (depending on exit/entrance)	• Vertical transport: elevator and stair • Pathways: within MRT: good, in between: bad, in platform: bad • Disable: not possible	Integration: 2 Easiness: 2 Comfort: 2 Transit distance: 2 Transit time: 2 Convenient facilities: 2

Transit Process: Transit can be done among these five transport modes, particularly between BTS and MRT and between BTS or MRT with other transport modes. Transfer from BTS to bus especially at Sukhumvit road seems the easiest one as the bus stand is right below the BTS station. To some extent, transfer between BTS and MRT (for a particular exit/entrance) as one exit of the BTS is right in front of one MRT entrance. The summary of transit process is shown in Table 8.

4.5 Saladaeng-Silom Transit Hub

Physical Feature: This hub features the connection of BTS, MRT, Bus, Taxi, and Motorbike Taxi. This hub does not support people with disability. Survey shows that transit at this hub from BTS to MRT requires 8 minutes. The distance between the exit/entrance of BTS and exit/entrance of MRT is about 150 meters. The BTS Saladaeng Station is a bit far from the junction of Rama IV-Ratchdamri-Silom Roads. The walkway from BTS to MRT is a short Sky Bridge and down to the entrance of BTS by using stair. The schematic situation of Hub is seen in Figure 8.

Transit Process: The shortest transit at this hub is between BTS and bus bound for southwest direction, as the bus stand is below the premise of BTS Saladaeng Station. The longest transit occurs when a BTS traveler would change the transport mode to a bus bound for Hualamphong (west direction). He/she must walk for about 250 meters with uncomfortable pathways particularly after get out from BTS exit. The walkway is not so convenient for walking children or loads. With respect to integrated-ness, the hub is poorly integrated. This feature is most probably because of timely-separated planning with different planners and implementers.

The summary of result of transit survey at Saladaeng-Silom Transit Hub is presented in Table 9. The survey was undertaken at non-peak hours around 10-11am.

4.6 Saphan Thaksin-Sathorn Transit Hub

Physical Feature: This hub is actually not that important. However, it is included in the assessment as it needs to include a different kind of transport modes. Saphan Thaksin-Sathorn hub connects mainly BTS at Saphan Thaksin station and Boat River Pier of Sathorn with the additional bus, taxi, motorbike taxi, and songteaw. Survey reveals that taxi and motorbike taxi is available anywhere particularly in any transits and junctions. These transport modes have made intermodal transits easier, even though it is still far to serve the convenience of disabled people. This hub is shown in Figure 9.

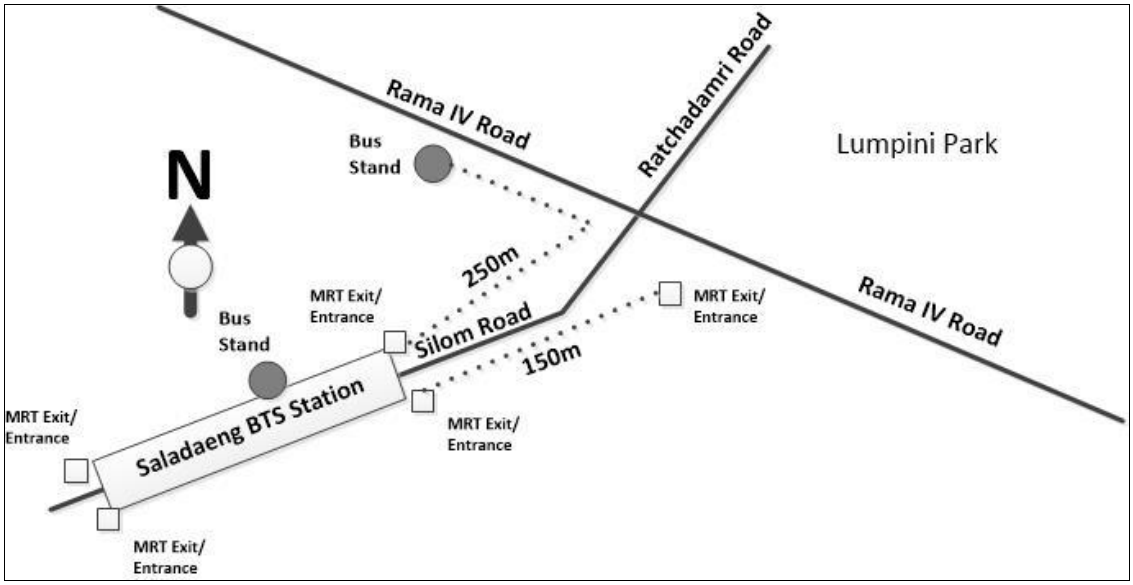

Figure 8 Silom-Saladaeng Hub
(Transport Modes: BTS, MRT, Bus, Taxi, Motorbike Taxi)

Table 9 Summary of the Transit Process Survey in Saladaeng-Silom Transit Hub

Transit Process	Quantity of Transit	Quality of Transit	Own Rating (1:worse, 5:excellent)
MRT to BTS	• Time required (gate-to-gate): 3 minutes • Vertical Distance: 20m by escalator+10 meter stair • Horizontal Distance: 150m	• Elevator available at MRT • Vertical transport: escalator and stair • Pathways: within MRT: good, within BTS: good, in between: bad • Disable: not possible	Integration: 2 Easiness: 2 Comfort: 2 Transit distance: 2 Transit time: 2 Convenient facilities: 3
BTS to Bus/Taxi/Motorbike Taxi	• Time required: 5 minutes • Vertical distance: 10m stair • Horizontal Distance: 50m	• Vertical transport: stair • Pathway within BTS: good, in between: bad, at platform: bad, disorder • Disable: not possible	Integration: 2 Easiness: 2 Comfort: 2 Transit distance: 3 Transit time: 3 Convenient facilities: 3
MRT to Bus/Taxi/Motorbike Taxi/Park and Ride	• Time required: 3-10 minutes (depending on exit/entrance location) • Vertical distance: 20m by elevator • Horizontal Distance: 20-80m (depending on exit/entrance)	• Vertical transport: escalator • Pathways: within MRT: good, in between: bad, in platform: bad • Disable: not possible	Integration: 2 Easiness: 2 Comfort: 2 Transit distance: 2 Transit time: 2 Convenient facilities: 2

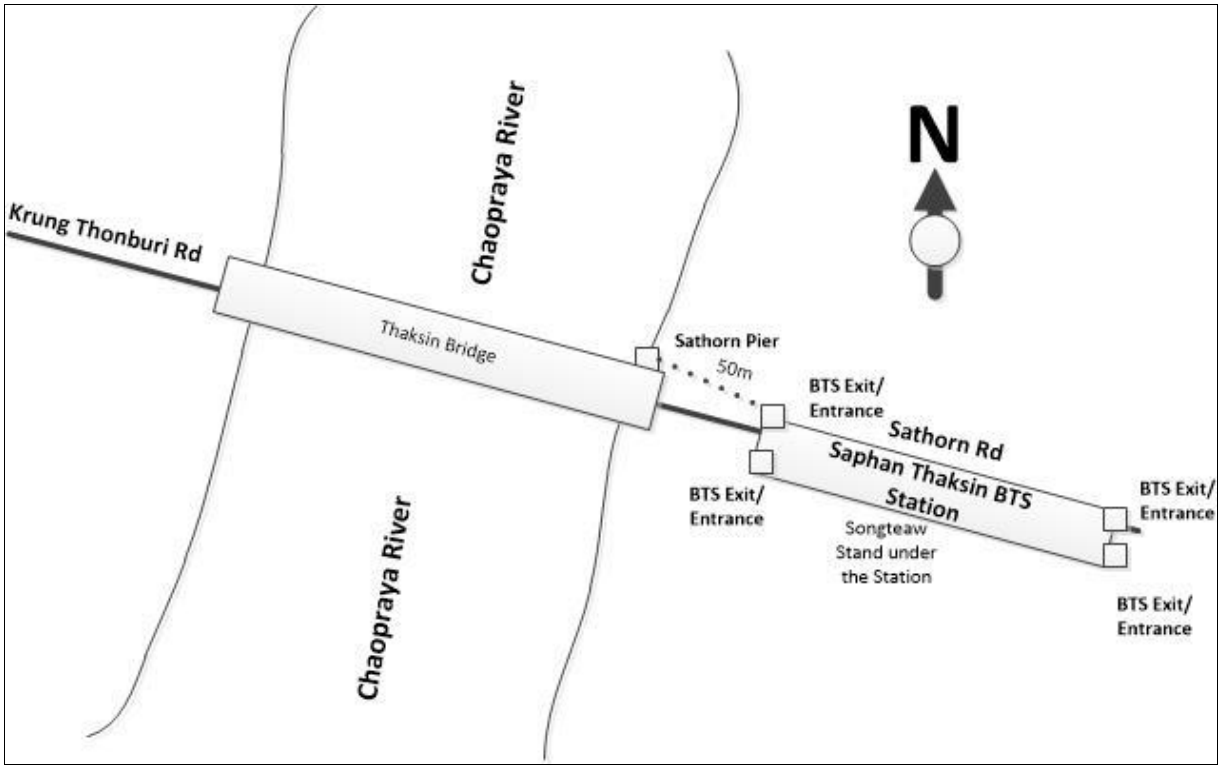

Figure 9 Saphan Thaksin Hub
(Transport Modes: BTS, MRT, Bus, Taxi, Motorbike Taxi, Songteaw)

Table 10 Summary of the Transit Process Survey in Saphan Thaksin-Sathorn Hub

Transit Process	Quantity of Transit	Quality of Transit	Own Rating (1:worse, 5:excellent)
BTS to River Boat	• Time required: 5-10 minutes (depending on the exit) • Vertical Distance: 10m by stair • Horizontal Distance: 50-150m (depending on the exit)	• Vertical transport: stair • Pathways: within BTS: good, in between: bad • Disable: not possible	Integration: 2 Easiness: 2 Comfort: 2 Transit distance: 3 Transit time: 3 Convenient facilities: 3
BTS to Bus/Taxi/Motorbike Taxi	• Time required: 5-10 minutes (depending on exit) • Vertical distance: 10m stair • Horizontal Distance: 50-150m (depending on exit)	• Vertical transport: stair • Pathway within BTS: good, in between: bad, at platform: bad, disorder • Disable: not possible	Integration: 2 Easiness: 2 Comfort: 2 Transit distance: 3 Transit time: 3 Convenient facilities: 3

Transit Process: BTS in Saphan Thaksin station is equipped with an escalator. However, transit for disabled people is not possible. Transit from BTS to riverboat is facilitated by Sathon Pier. The distance from the pier to the closest BTS exit is about 50 m through a crowd of food street vendors, Songteaw stand, and Tuktuk stand. The pathway is therefore inconvenient. The bus stand is available with a distance of 100 meters from the station. But the transit will not be convenient, as the pathway is uneven and crowded. It seems that this hub was planned when the surrounding areas have already developed, and thus makes the overall transit process is not convenient. The survey results at this hub are seen in Table 10.

5. Modified Quantitative Gap Analysis

There are numerous assessment tools for both qualitative and quantitative evaluations. Some of them are, for example, Affinity Charting, Analytical Hierarchy Process, Balanced Score Card, Cause and Effect, Gap Analysis, SWOT Analysis, Quantitative Decision Making, Total Quality Management, and many others. Gap Analysis is basically employed since the study attempts to

understand the fact, as assessed by users and authors, against the ideal situation as preset by the authors based on some previous studies and authors' opinion. This study employs Modified Quantitative Gap Analysis (MQGA) with the following grounds: (a) to avoid subjective assessment as the original gap analysis identifies only existing and ideal condition, then gap based on the ideal and the existing states (b) to understand the gaps between existing and ideal condition (c) to identify the possible strategies to close the gaps.

To employ the MQGA, the evaluation by the users and authors are quantified. There are some variables used to assess the seamlessness of the transit system in Bangkok, namely, integration, easiness, comfort, transit distance, transit time, and convenient facilities. During the survey, plain explanations to avoid the ambiguity of the respondents were given. The following plain terms are given to the respondents during the survey.

Integration: the unity of premises/stations of BTS, MRT, ARL, Bus Stops (weighting factor, w=0.2)
Easiness: transit will bring no various suffers to the users (w=0.2)
Comfort: premise provides protection from the weather, provide air conditioners, easy and even walkways (w=0.2)
Transit distance: relatively close, it does not create enforced walk (easy breathing) (w=0.15)
Transit time: relatively short time, it does not make the travelers late and in rush (w=0.15)
Convenient facilities: the premises are equipped with facilities such as stores, ATM, and toilets (w=0.10)

A quantified respond is given to the respondents with the 5-scale response, such as 1(worse), 2(bad), 3(satisfy), 4(good), 5(excellent).

A weighting factor for each element is introduced since each element does not have a similar contribution to the seamlessness. For instance, convenient facilities are only additional facilities for the overall function of the transit process, therefore the weighting factor is the lowest. On the other hand, the easiness, the comfort, the integratedness (integration of the premises of a transit hub) of the hubs are the most important elements. Therefore their weighting factors are the largest. Transit distance and transit time are normally the same elements, and thus the weighting factor is the same. The total weighting factors for all elements must be 1.0.

The following formula is used to quantitatively identify each element of the seamlessness of a particular transit hub:

$$c_i = \sum_{i=1}^{n} \frac{1}{n} [(r_i - \bar{r})^2]^{0.5}$$

And the seamlessness of a particular transit hub is computed by using the following formula:

$$S_i = \sum_{i=1}^{n} (c_i \cdot w_i)$$

c_i Element of seamlessness
w_i Weighting factor of each element of seamlessness
r_i Responses from the individual user on a particular issue
S_n Seamlessness of a transit process at the particular transit hub
N Number of sample of the transit hub
n Number of respondent who responds to a specific question
i Elements of the seamlessness
j Individual selected station

With the interval scale of response is 1.0, the quantified criterion of seamlessness is divided into four into different intervals with the interval skewed towards seamless, the following criterion based on the quantified scale of the responses is as follows:

- Perfectly seamless i.e. easy and smooth transit if Sn <0.10
- Somewhat seamless if Sn: 0.10-0.20
- Hard transit if Sn:0.21-0.50
- Not a smooth transit: Sn>0.50

Performance of individual element at the different station is computed according to the following formula:

$$p_i = \frac{1}{n} \sum_{i=1}^{n} r_i$$

The seamlessness of overall Bangkok Transit Hub, based on six selected transit hub is computed by the following formula (assuming that each selected hub contributes to the Bangkok Transit System equally. Note: figure 6 in the formula exhibits the number of selected transit hub):

$$S_o = \frac{1}{6} \sum_{i=1}^{6} S_i$$

Based on 300 responses or 50 responses from each transit hub, by using the above formulas, the performance of each station in terms of individual elements of seamlessness, the seamlessness of individual elements, and the seamlessness of Bangkok Transit System based on selected hubs are shown in Table 9. And the performance of the individual hub on each element of the seamlessness is presented in Table 10.

Table 11 Seamlessness of individual hub

Hub	Seamlessness (Sn)
Mochit-Chatuchak Park	0.54
Phayathai	0.34
Makkasan-Petchburi	0.35
Sukhumvit-Asoke	0.49
Saladaeng-Silom	0.47
Saphan Taksin-Sathorn	0.42
Bangkok Overall	0.43

Perfectly seamless: Sn <0.10
Somewhat seamless, Sn: 0.10-0.20
Hard transit, Sn: 0.21-0.50
Not a smooth transit, Sn>0.50

Table 11 shows that, with respect to seamlessness of the transit hub in Bangkok Metropolitan none of the selected hub exhibits a perfect seamless transit as the seamlessness value is all above 0.10. Two least values of seamlessness are shown by Phayathai and Makkasan-Petchburi Transit Hub, which are their values are 0.34 and 0.35 respectively. In fact, in Phayathai, for example, the distance among intermodal transports are so close, no more than 50 meters. The longest distance is between BTS and ARL, meanwhile the distance of other modes are between 10-20 meters. In Mochit-Chatuchak's case, the seamlessness is higher as the distance among intermodal transports are mostly, which is more than 50 meters. The farthest is between MRT and BTS, which is about 200 meters, and the path between the two is uneasy to pass.

Table 12 exhibits the average perceptions of the intermodal transit hub users, with the scale of 1 (worse) to 5 (excellent). Since these are the perceived values, the results are not definite, instead approximate to understand the level of six variables of the transit process for each selected hubs. It may or may not exactly represent the reality of public transport system in Bangkok in general.

Table 12 Performance of individual Hub on each element of seamlessness (based on 300 respondents)

Hub	Integratedness	Easiness	Comfort	Transit Distance	Transit Time	Convenient Facilities
Mochit-Chatuchak Park	2.34	2.28	2.20	2.14	2.14	3.06
Phayathai	2.80	2.80	2.02	2.92	2.84	2.14
Makkasan-Petchburi	2.00	2.24	2.10	2.08	2.10	2.22
Sukhumvit-Asoke	2.24	2.50	2.26	2.46	2.44	3.16
Saladaeng-Silom	2.16	2.14	2.02	2.04	2.10	3.06
Saphan Taksin-Sathorn	2.04	1.98	2.00	2.22	2.16	2.74

NOTE: 1: Worse; 2: Bad; 3: Satisfactory; 4: Good, 5: Excellent

6. Conclusions

Six primary public transit hubs have been selected for the study, among about 17 existing hubs. Based on the responses of the transit users, and scientific judgment of the seamlessness referencing to sustainable transportation system, the transit process in Bangkok public transportation system, which involved formal, semi-formal and informal public transport namely Mass Rapid Transit System (MRT), Bangkok Mass Transit System (BTS), Airport Rail Link (ARL), State Railway of Thailand East Track (SRTET), Bangkok Bus System, Taxi, Motorbike Taxi, River Transport System, Songteaw, and private cars, exhibits a level of challenging transit process. Not to mention the transit process carried out by disabled and disadvantaged people.

With respect to the comfort of the individual premise of the station, as exhibited by Mass Rapid Transit System, Bangkok Mass Transit System, and Airport Rail Link, the user's perceptions reflected satisfactory responses, with MRT as the most satisfactory responses followed by BTS and ARL. In the meantime, the other public transport modes received unsatisfactory responses to the comfort of their platforms and shelters. However, when the assessment was done for overall integrity as a transit hub, the satisfaction of the users goes down significantly. This is understood as the system was planned and implemented individually without an appropriate integration. As a result, the transit process is not considered smooth, comfort and seamless by the users. The users were particularly assessed from the performance of pathways between the transport modes. To accomplish a more seamless transit process, the improvement must be made particularly on the pathways/walkways between the transport modes. Presently, the pathways perform differently with significant disparities, from worse to excellent.

The present of convenient stores, malls, ATM. Banks, or other service hubs and other facilities, have made the perception better. It is reflected in the user's perception of Mochit-Chatuchak, Saladaeng-Silom and Sukhumvit-Asoke Transit hubs, where convenient stores, malls, and other facilities are abundant. If these prospective facilities were impeccably treated to boost their potential to support the seamless transit, the perceptions would considerably improve. These are supposed to be attended by the authorities in Bangkok Metropolitan.

By these findings we understand that the transit processes in selected intermodal transit hubs in Bangkok do not reflect a seamless transit, and therefore the shift of private transport users to be public transport users will not take place. This happens since each elements of intermodal transport was not implemented at the same time, and by different authorities and implementers. A coordinated authorities led by Bangkok Metropolitan Administration should be established. A single plan or a coordinated transportation plan should also be in place, rather than silo-like plan.

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