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Costing and Statistical Investigation of Steel Bars Produced from Scrap in Lagos State, Nigeria

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Abstract This paper reveals field survey of ten year price distribution and the degree of uncertainty or dispersion in the size geometry of local and imported bars. The study separates cost price and strength the main parameters needed when selecting ideal steel rebars, which is very fundamental to the development of reliable standard of practice for building and civil engineering industry. Lagos highland especially Ogba reinforcement bars sample has the highest mean, standard deviation and coefficient of variation (COV) of Y25 (24.8), Y16 (σ 0.095) and (0.81%) respectively. Likewise, the study of the price from various Lagos zone (island and highland) would enable the engineers, project managers or clients construction professionals to assess whether the price different or matches the strength difference. Finally, the research investigation is a basis for the development of acceptable standards or codes of practices for design that takes into account the geometry and strength of materials for construction of RC building and civil infrastructure in Nigeria.

Keywords Dispersion Degree, Costing, Lagos, Steel Rebars

1. Introduction

Reinforced concrete, as the most widely used construction material, plays a vital role in global economic growth and infrastructural development (Rojacz et al. 2013; Yeon et al 2007; Basu et al 2004). Reinforced concrete is a composite material made up of concrete plus reinforcing bars (rebar). Concrete as a brittle material, has slight tensile strength, which is an adverse trait for a construction material (Ede 2010; Hashemi 2006; Logan 2000).

In actual fact, reinforced concrete constitutes over ninety percent (90%) of infrastructure systems in unindustrialized or developing republics, even with the advances in

emerging technologies as well as innovative materials, not less than seventy- five percent (75%) is being utilized for constructed amenities in the industrialized countries (Balogh and Vigh 2013; Ede 2010; kosmatka et al. 2003). The networks of civil infrastructure as well as constructed facilities for example bridges, roads, buildings, tunnels, dams and retaining wall, telecommunications installations, transportation systems, water resources, nuclear power plants, and wastewater systems and other life-supporting facilities aid in delivering essential services, shelter provider, structural foundations, support social teamwork and economic improvement (Harara et al. 2013; Vigh 2013). For all intents and purposes, the sustainable economic growth, throughput or productivity, and the good fortune of a nation is being determined heavily based on its functionality, consistency or reliability, as well as durability of its civil infrastructure structures (Balogh and Vigh 2013; Yeon et al. 2007).

Rebar is introduced to concrete to increase its ductility and to regulate widths of crack (Harara et al. 2013). Whether the rebar is made of fiber reinforced polymers or steel, tensile stresses must be transmitted from the concrete to the rebar. The transfer of stress from the concrete to the rebar is achieved through bond amongst the two materials (Balogh and Vigh 2013; MIT 1999). In order to achieve an acceptable probability or likelihood that any designed structure might perform satisfactorily all through their intended life, steel rebar must compliance with design code specification before used during construction deeds (Maghsoudi and Akbarzadeh 2006; Basu et al. 2004; Oyenuga 2000). BS 1881-124: 2015 and BS 8110:1-2002 testified that concrete materials is often hampered by non-conformity with structural design stipulations and non-conformance of structural properties of materials utilized in the actual construction compared, to the properties of materials specified at the designed stage. In recent times, structural catastrophe of both building and civil infrastructure is on the rise in Nigeria. Even if structure has sound analysis and design it can still fail, if

the quality of the material utilized for the construction is bad. Statistics have exposed that a significant number of structural catastrophes could be credited to influx of impostors and/or wrong professional practices, bad material quality, poor construction approach, workmanship and unsubstantiated newly introduced reinforcement (Erhard 2006; Chahrour and Soudki 2005; Castro et al. 2002; Clifton and Marthey 1983).

The two major materials utilized for constructional reasons in reinforced concrete structures are reinforcement bars and concrete. Attaining an acceptable possibility that any designed structure can perform satisfactorily during their envisioned life is frequently hampered through non-compliance of structural design specifications as well as non-conformance of structural properties of materials used in the real construction to the properties of materials indicated at the designed stage (Balogh and Vigh 2013; Bellis 2011; Clifton et al. 1999; MIT 1999). In contemporary times, structural failure of civil as well as building infrastructure is upsurge in Nigeria (NIS 1992). Despite the fact that so many investigations and probes have been performed on the worrisome trends of structural collapse in Nigeria from social sciences, environmental as well as engineering points of view (Ede, 2010; Oyenuga 2000; Phillips 1998), this study attempts to address the impact of dispersion coefficient, and also related issues, as well as the effects of prices on various aspects of characterization of locally produced steel reinforcing bars (rebars)

1.1. Historical Overview of Steel Production in Nigeria

Rebars are rolled from billets that are found from a furnace (Rojacz et al. 2013; Yeon et al. 2007). Billets can be formed either from iron-ore through the blast furnace converter channel, or by melting scraps as well as refining the same in the furnace (Erhard 2006; Gilchrist and Thomas 1879). The prominent steel companies in Nigeria are the Delta Steel Company Limited, Aladja, Warri as well as the Ajaokuta Steel Company Limited, Ajaokuta. These two corporations manufactured steel from unprocessed or raw materials either as finished products or steel billet which are semi-finished products. The companies supplied billets to the three inland rolling mills, which are Oshogbo Steel rolling company, Oshogbo, Katsina Steel rolling company, Katsina and the Jos steel rolling company Jos (Ede 2010; Oyenuga 2000). These rolling companies manufactured the finished steel products from billets. The Delta steel corporation, Aladja has yearly rolling capacity of three hundred and two thousand (320,000) tonnes whereas the Ajaokuta Steel Company Limited

had a design capacity of one point three millions (1.3 millions) tonnes. Every one of the three steel rolling companies, Oshogbo, Jos and Katsina had a rolling capacity of two hundred and ten thousand (210,000) tonnes. These companies, nonetheless, are categorized by low capacity utilization attributable to lack of adequate sourcing of raw materials or semi-finished products, as well as effective funding for maintenance and technical operations (Kayali and Zho 2005; Phillips 1998).

Locally manufactured or factory-made reinforcing steel bars from scrap metal are becoming very common in Nigeria in particular and Africa at large. In developing republics such as Nigeria where imported steel manufactured to world best standards is at high-priced, milling companies as well as private individuals have taken up the challenge or conundrum to re-cycle obsolete vehicle, machine metal parts and household metal rubbish or waste for the production of structural and reinforcing steel. The typical of the registered indigenous steel rebar manufacturing industries that use scraps as their major raw materials for producing steel include Nigerian Spanish Engineering Ltd, Kano, African Steel Nig. Ltd, Ikorodu, Lagos, Continental Iron and Steel Company (CISCO) Ikeja, Lagos, Unique Steel Industres, Ltd, Lekki, Lagos, Universal Steel Company Ikeja, Lagos, Sun Flag Nigeria Ltd, Ikorodu, Lagos, among several others. In actual fact, preliminary investigations publicized that there are scores of such local steel companies operating in Nigeria, legally and illegitimately (Ede, 2010); Oyenuga 2000; Phillips 1998).

To cut a long story short, the steel reinforcing bar required for structural concrete is partially or partway produced by the country's inland rolling mills while the balance is sourced through import. The importation is carried out mostly through private entrepreneurs and the attribute of such imported product is always neither guaranteed nor sure fire, as they are essentially brought in from diverse sources without any comprehensive as well as methodical standardization process regarding their structural properties (Kankam and Adom-Asamoah, 2002; Kankam and Odum-Ewuakye 2001; Logan 2000; Neville and Brooks 1994). Consequently, differences are bound to arise in the strengths, and feasibly, geometry of steel assumed in design as well as those used for actual construction, unless tests are carried out on every batch of imported steel delivered on construction site. With the near collapse of the government-owned rolling mills and dwindling performance of the privatized counterparts in an unfriendly economy, influx of steel rebars from questionable sources are the order of the day in Nigerian markets.

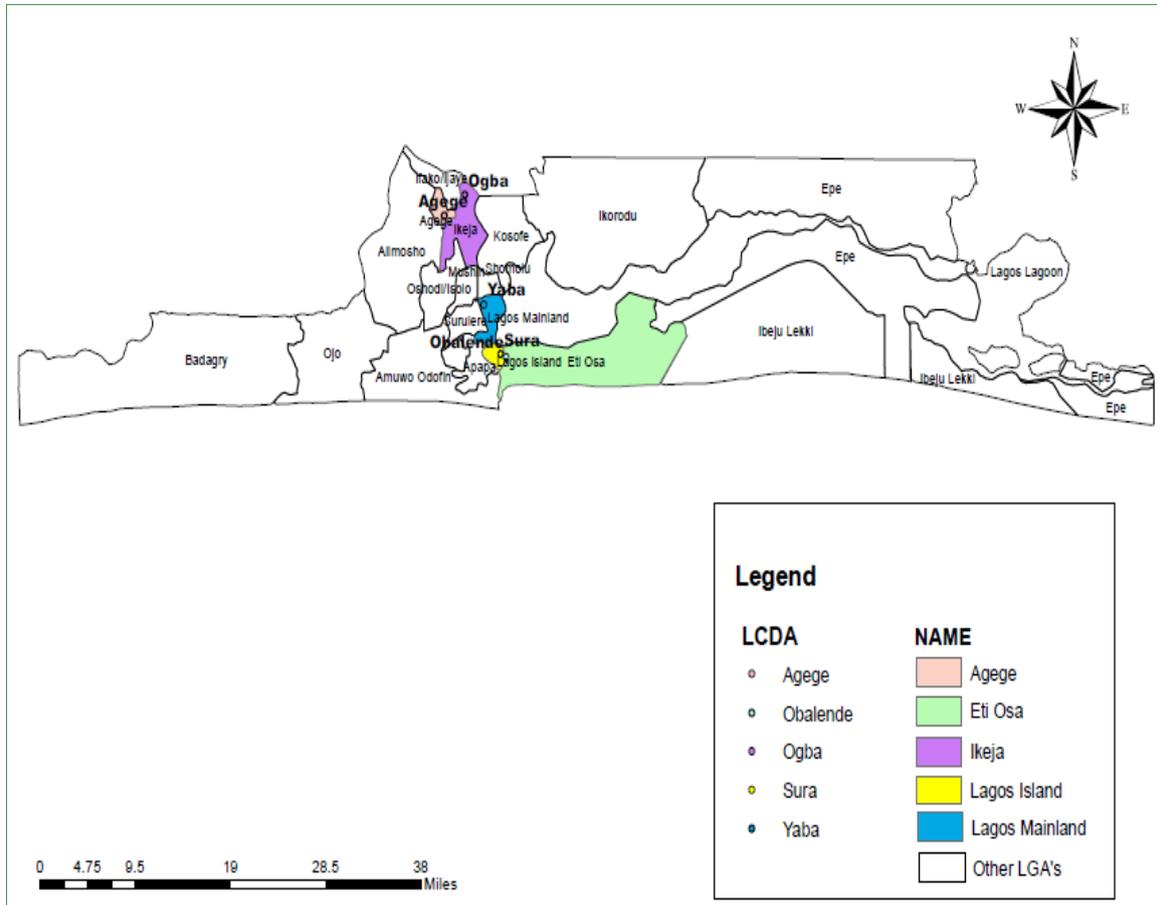


Figure 1. Lagos state map showing the study localities for both island and highland

2. Methodology

2.1. Study Zone Description

Lagos is a state in the southwestern geopolitical region as well as the largest Nigeria state with GDP of US\$33,679 million, the nation-state's largest urban district, major financial center, one among fastest developing metropolises in the world and fourth (4th) highest GDP as well as largest economy in Africa. This megacity houses largest and busiest seaports at Apapa, Lagos Island and international airport at Ikeja, Lagos highland. It is bordered on the north as well as to the east by Ogun state, while in the west the Republic of Benin. In the rear, its southern boarders lies the Atlantic Ocean with twenty-two percent (22%), out of its 3,577 Km² are lagoons as well as creeks with coordinates of 6^o 35N and 3^o 45E, which also graphically demonstrated in Figure 1.

2.2. Materials and Methods

Field survey which includes market survey/pricing and statistical evaluation of size distributions of locally made steel rebars. Size distribution of the steel rebars was carried out through market survey of two different zones namely

Lagos island and highland. A total of fifty (50) steel rebar major distributors was visited in each of the two zones so as to determine the real sizes of different steel rebar types available. Ten year market price survey was conducted per tonnage of 10 mm – 25mm diameter steel rebar for local types.

3. Result and Discussion

3.1. Statistical Analysis of the Lagos Steel Bars Distribution

Mean Value

The mean values of steel rebars recorded from five localities are presented in Figure 2.

Standard Deviation

The standard deviation values of steel rebars recorded from five localities are presented in Figure 3.

Coefficient of Variation (COV)

The coefficient of variation value of steel rebars recorded from five localities is presented in Figure 4.

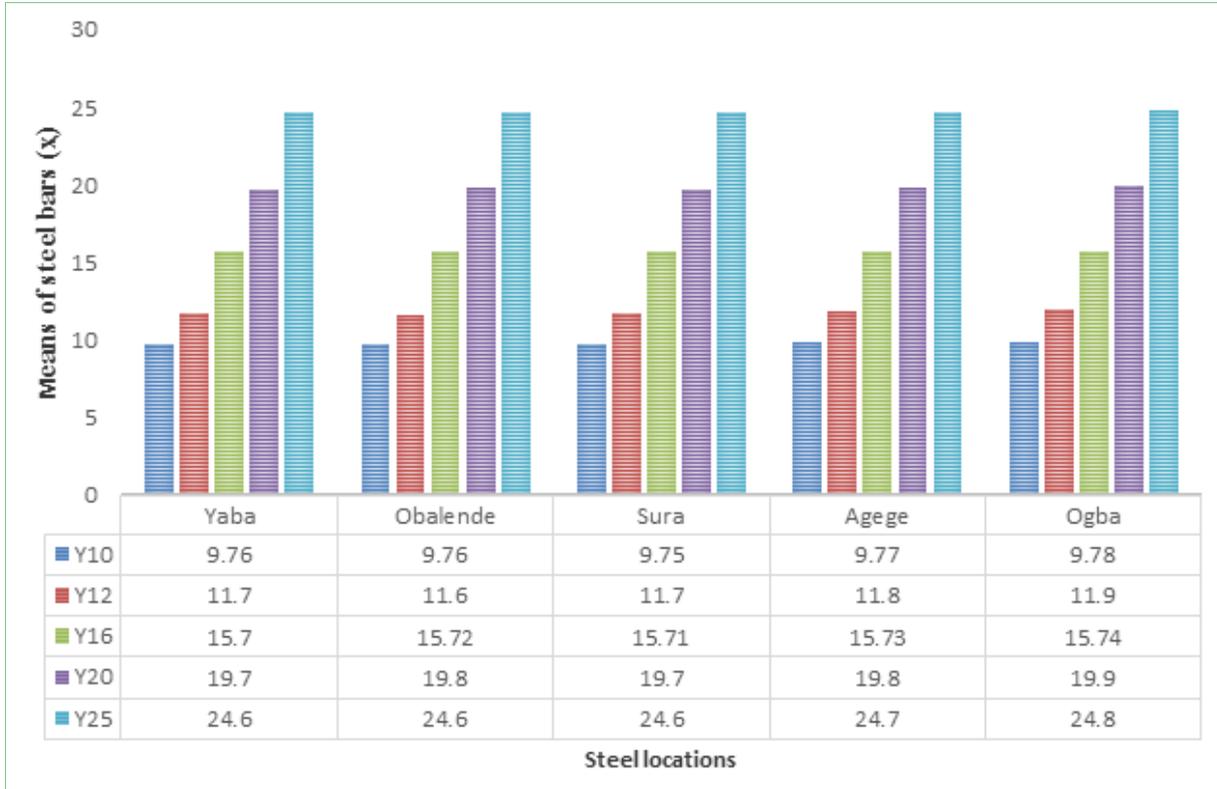


Figure 2. Means of steel bars from various locations

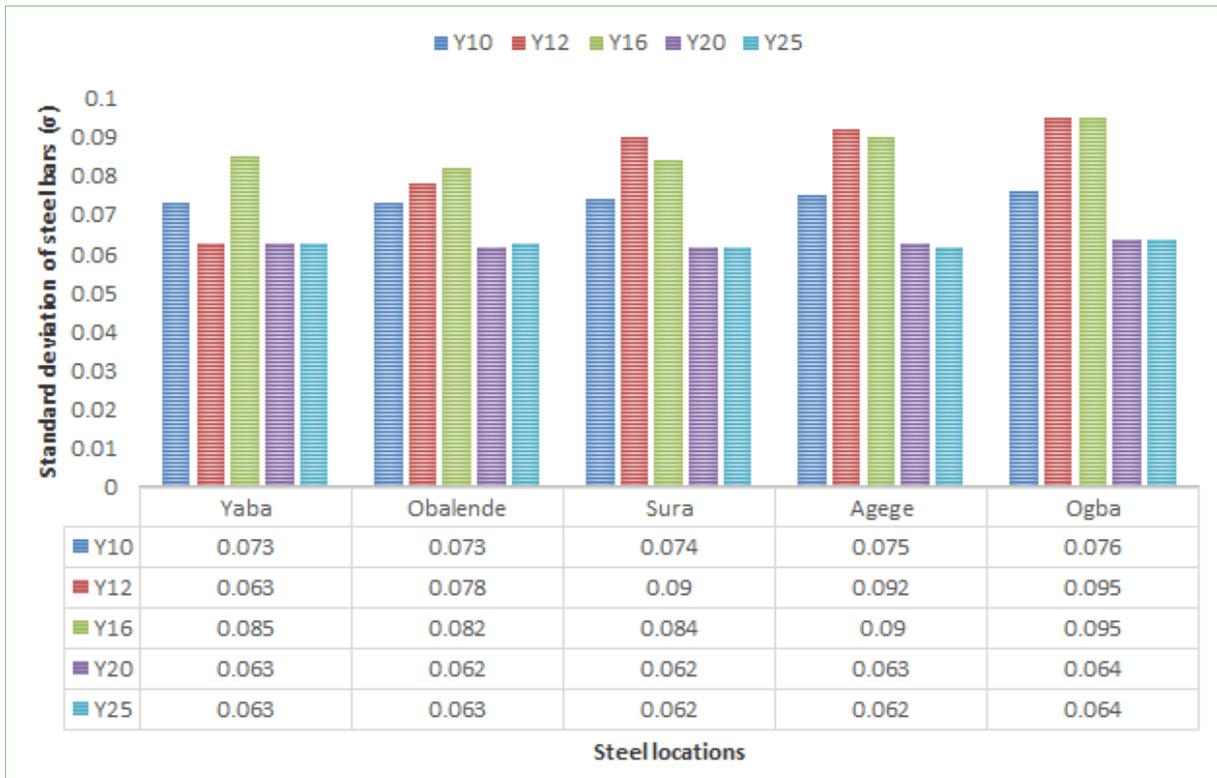


Figure 3. Standard deviation of steel bars from various locations

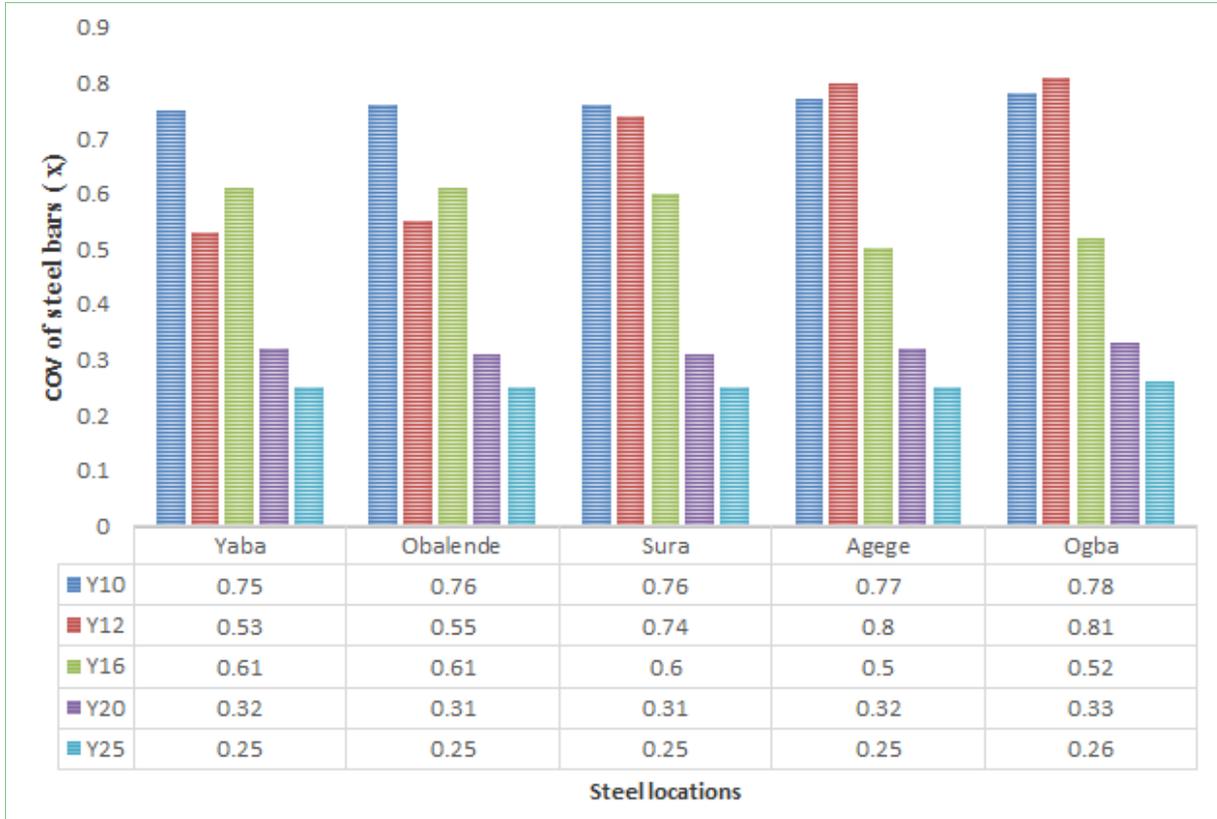


Figure 4. Coefficient of variation (COV) of steel bars from various locations

Figure 2 - 4 reveals that Ogba reinforcement bars sample has the highest mean, standard deviation and coefficient of variation (COV) of Y25 (24.8), Y16 (σ 0.095) and (0.81%) respectively.

All the parameters were consider for the steel rebars of range 10 mm to 25 mm are the mean (\bar{x}), standard deviation (σ), variance (σ^2) and the coefficient of variation (COV). The coefficient of variation give the most reasonable consideration, it shows the percentage of standard deviation to the mean.

It is obvious that in Lagos metropolis, the mean bar sizes for the different diameter of rebars considered for the Lagos highland are higher in diameter that the corresponding Lagos island type, with a very small margin. That is, Highland reinforcing bars, mean value is within 9.77 to 24.8 and the Lagos Island reinforcing bars in the range of 9.75 to 24.6 for the same diameter size range. Meanwhile, for Highland reinforcing bars, standard deviation value is in the range of 0.064 to 0.075 and the Lagos Island reinforcing bars in the range of 0.063 to 0.073 for the same diameter size range. Also, there is a smaller degree of uncertainty in the Lagos Highland reinforcing bars size having COV in the range of 0.26 to 0.77 and the Lagos Island reinforcing bars in the range of 0.75 to 0.25 for the same diameter size range. Therefore, from the analysis, imported bars in relation to the sizes specified by British standard can still be considered for structural

purposes, though not without proper assessment of the tensile strength properties. The statistical analysis of steel size distribution can be compared to that of Lagos highland because of the big market for steel in Lagos highland which is source of supply to Lagos island metropolis.

From the two study areas, the degree of uncertainty in Lagos Island is small compared to that of Lagos highland. However, if we have to consider the sizes of steel made with imported billet and thermo mechanically treated (TMT product), as testified by Ede (2010) and Phillip (1998), the degree of uncertainty is almost the same. This is probably due to recent monitoring by Standards Organization of Nigeria (SON) to ensure quality and standardized steel in the country.

3.2. Cost Analysis

The reinforcement costing values through random survey for ten (10) years are displayed in Figure 5. While, the variation between lower and high prices for reinforcement bars at five localities for ten (10) years are displayed in Figure 6.

Figure 5 indicates the trend for the costing of locally made, semi-locally made and foreign reinforcement from 2010 to 2019, While Figure 6 shows high fluctuations especially from year 2010 to 2019.

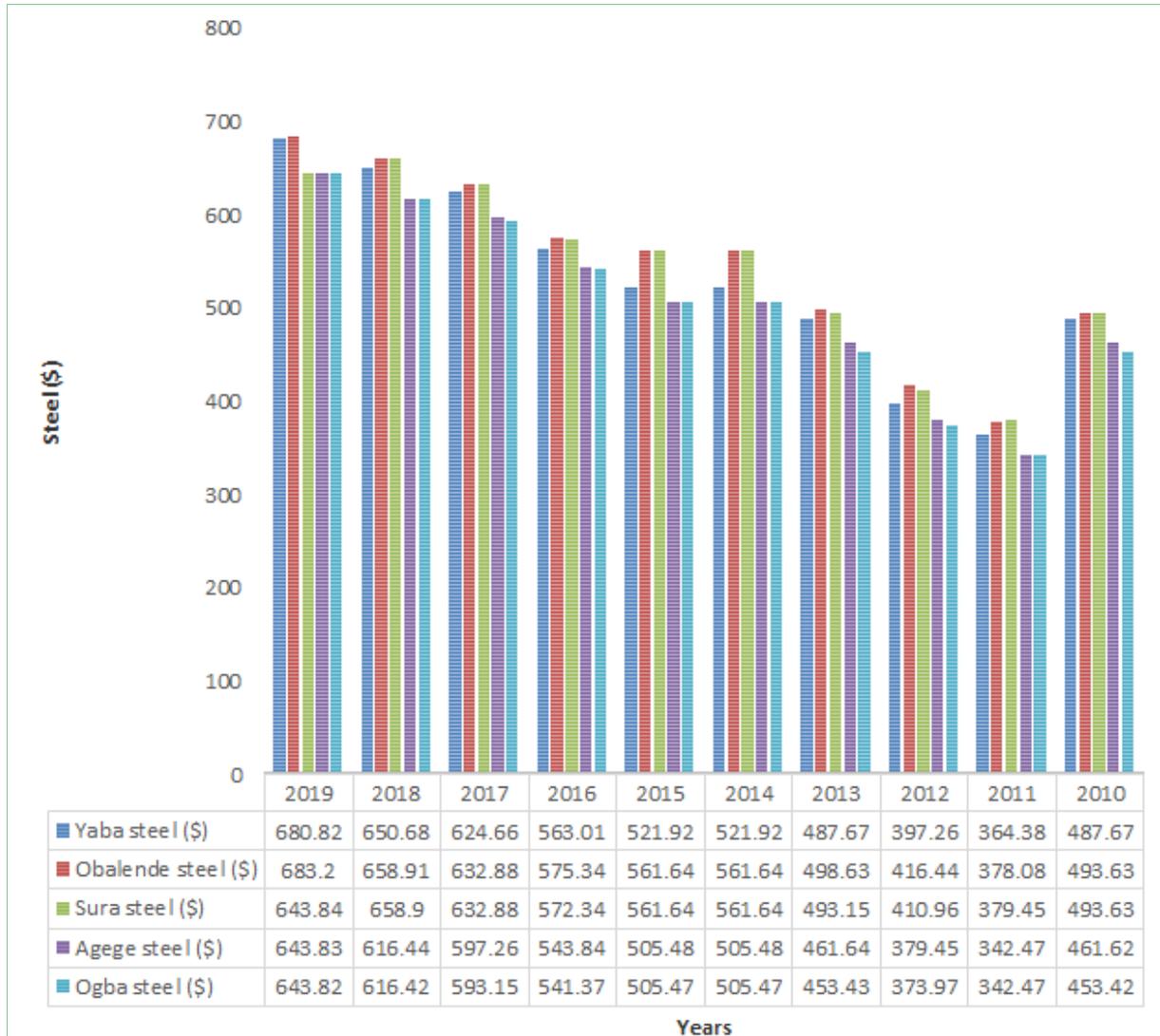


Figure 5. Costing of reinforcement from 2010 to 2019

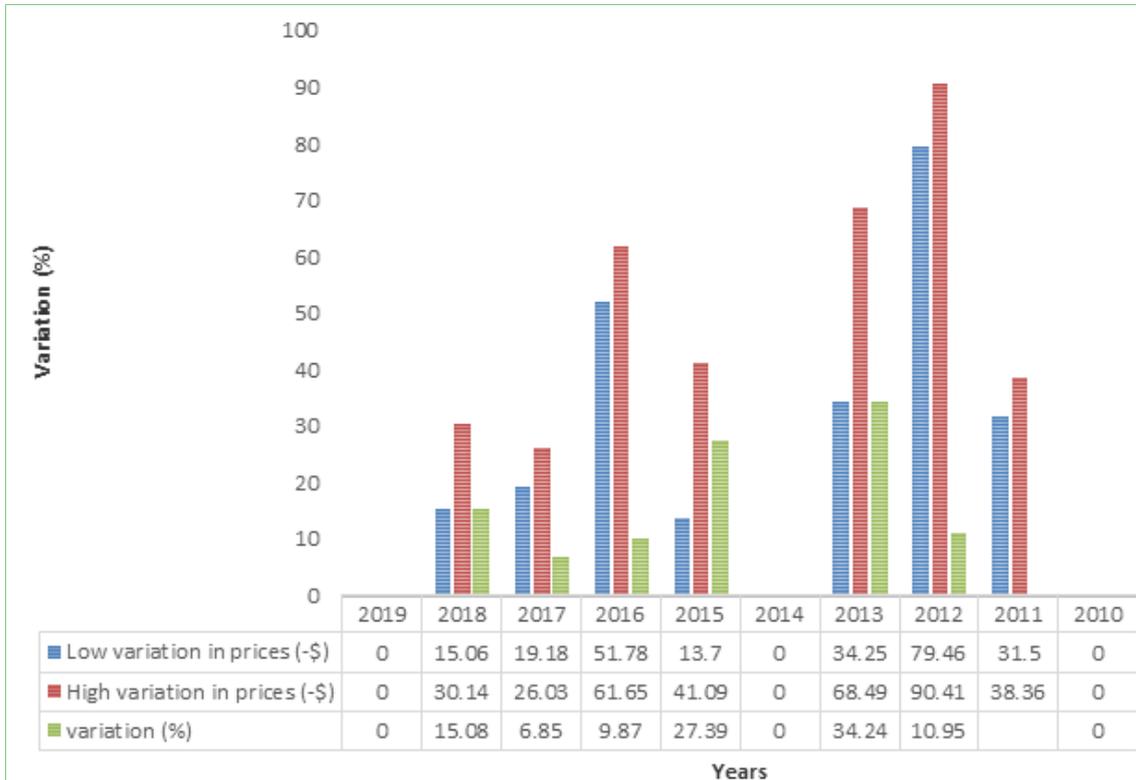


Figure 6. Variation between low and high prices

Lagos metropolis was taken as point of reference because of the huge steel industries location in this part of the country. It was perceived that there were wide variation in prices of steel brand based on vicinities and urbanization. It was also publicized that cost of reinforcement in Lagos Island is higher than Lagos highland; this may also be reason for constant building collapse at Lagos Island. The owners and contractor care less about strength requirement, because as developer making money from overcrowded population is their goal. The price survey is based on imported and local steel rebar for period of ten years. The value of imported and local steel rebar was at its apex value of \$ 493.63 in 2010, whereas in 2011 was \$ 379.45, But in 2012 the steel rebar was its peak value of \$ 416.44. From 2013 to --- it increasing rapidly with values of \$ 498.63; \$ 561.64; \$ 561.64; \$ 575.34; \$ 632.88; \$ 658.91 and \$ 680.82). The price of local and imported steel bars rising swiftly can be attributed to change in government and other factors like construction policies, increase in demand or when the regulatory bodies such as SON took the standard strength of steel into consideration, and increased nationwide awareness of the strength of steel in structural stability of concrete structure in the face of incessant collapse of built and on-going building and civil structures.

deviation and coefficient of variation (COV) of Y25 (24.8), Y16 (σ 0.095) and (0.81%) respectively. Also, the market price survey of Lagos reinforcement bars showed that Lagos highland areas were cheaper than Lagos Island (Yaba, Obalende and Sura). The price survey is based on imported and local steel rebar for period of ten years. The value of imported and local steel rebar was at its apex value of \$ 493.63 in 2010, whereas in 2011 was \$ 379.45, But in 2012 the steel rebar was its peak value of \$ 416.44. From 2013 to --- it increasing rapidly with values of \$ 498.63; \$ 561.64; \$ 561.64; \$ 575.34; \$ 632.88; \$ 658.91 and \$ 680.82). All locally made bar price trend was characterized by higher fluctuations. Though, engineer as well as builder patronize it, but compromised strength requirements especially in the island. Conclusively, the price of reinforcing steel bars growing expeditiously can be as a result of change in government and other factors such as construction policies, increase in demand or when the regulatory bodies like SON took the standard strength of steel into consideration, as well as increased coast-to-coast or nationwide awareness of the strength of steel in structural stability of concrete structure in the face of never-ending collapse of built and on-going building and civil structures.

4. Conclusions

This paper showed that Lagos highland especially Ogba reinforcement bars sample has the highest mean, standard

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The Boundaries of Representation of Architecture and Art in Public Space, International Architecture Biennial

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Abstract The physical environment generates myriad of values and comprises various connotations. These values and connotations, which are directly or indirectly represented by the output, generate a sampling area to understand the production and consumption forms of the physical environment, of its cultural, social and economic priorities and contextual relations. Therefore, architecture is utilized as a tool to understand the historical transformations and relations in various disciplinary fields while architectural criticism tries to understand the architectural building process and its outcome by exceeding its professional boundaries and observing the relationships between different disciplines and architectures. Literature, art, philosophy, politics are alternative means of expression, which complement architectural criticism. In this context, architectural biennials perform as periodical discussion platforms, which perform as an alternative space for the criticism and documentation of the current issues of architectural production and its most dire problems through a selection of works under a certain theme. The works exhibited at the biennial use different tools of narration in various disciplinary bases in addition to architecture itself, and therefore create an environment for generating content and values with multiple inputs for discussions as well as concepts defining the architectural outcome. In this paper, it aimed to discuss and evaluate the accumulation of works exhibited at the biennial with various contextual and conceptual arguments and interpretations, and the boundaries of functionalization of biennial exhibitions as a platform for architecture criticism.

Keywords Biennial, Architecture Biennial, Architectural Criticism, Public Space, Representation

1. Introduction

An architectural work is an object which is perceived by

a large group of people inevitably not just limited to its users, effecting its immediate surroundings in various scales and forms, carrying a meaning for both itself and its context and embodying a representative and a signature value. In other words, an architectural work, in addition to its primary function, undertakes direct or indirect subtasks and beholds meanings that relate to a common public memory. It represents the historical, cultural, traditional, ideological and political priorities and reversely it allows for the retrospective reading of many historical, sociological and political phenomena through architecture. This additional function of architecture becomes especially important and prominent in urban areas and densely populated central zones. On the other hand, building up architecture with certain qualities and sustaining its existence is directly related to the expectations, priorities and cultural structure of the consumer society as much as the professionals who physically produce it. The presence, sharing and consumption manners of architecture in public spaces are important both for the cultural environment of architecture and the boundaries of influence and transformation of that environment over architecture. Architecture uses a variety of tools to expand the boundaries of this interaction. Certainly, the main tool is the built environment itself. However, the knowledge of architecture tries to express itself utilizing directly the cultural setting and means of communication by means of various publications, exhibitions and activities and also to functionalize a critical cultural environment within disciplinary relationships.

In recent years, architectural biennials stand out among these tools as their numbers gradually increase. Biennials, such as Venice, Sao Paolo, Rotterdam, Chicago, Seoul, Hong Kong, Shezhen by hosting exhibitions, events and temporary interventions on the public space, contribute to the development of a sustainable culture of critical thinking within the profession and also contribute to the development a culture of participation on debates concerning architectural and environmental issues for the

inhabitants using these public spaces. Likewise, the International Architecture Biennial Antalya organized by The Chamber of Architecture of Turkey, Antalya Branch, is on its way to become institutionalized as it has already completed its fourth exhibition. In terms of both its schedule and content, the biennial shows similarities to other international biennials and also has its unique features.

The unique context of Antalya city and the relationship with the public space is what mainly sets it apart from its peers. Antalya combines the traditional and contemporary architectural texture tightly knit together, and this complex structure allows for an authentic contextual and sampling environment with its population gradually becoming more cosmopolitan. This authenticity is reflected in the works created for the International Architecture Biennial Antalya, especially the Experimental Architecture Works in public spaces create a basis for inquisitive, critical and instructional feedbacks regarding both the architectural output and their relationship with the urban context.

The works exhibited at biennials aim to have a connection with different groups of audiences via a problem, concept, research idea or an experimental work which is directly or indirectly related to the content and theme of the biennial. Therefore, the works exhibited at biennials not only make use and functionalize the hosting disciplinary field but also other fields which help convey the main message in a strong manner. Architecture biennials which make use of the built environment and the physical inputs effecting that environment in addition to other contextual inputs such as art to history or economy to culture as a venue, create a more inclusive and diverse environment for exhibition and can easily expand to different disciplinary fields. In spite of this extensive area of description, no matter what the background idea refers to, especially the main disciplinary field used for presentation and communication environment is art. In other words, biennial find its expressions on public space by functioning the methods and interpretations which are typical to art. That is to say, architecture biennial while making a statement on urbanism and architecture it also represents the intersection, continuity and conflict between art and architecture. Reversely, these statements made on urban areas presented to the city and audience, are not just limited to architecture but also contains an artistic expression.

This study aims to understand, to sample and to evaluate the experimental works presented at the International Architecture Biennial Antalya in relation to the urban context and public space and by means of discussing the boundaries of representative relationship between public space and architecture in order to understand the biennials as a critical platform. The study approaches to the examples selected from experimental works and installations in various zones of Antalya city with various urban fabric and variety of public characteristics. The influence and transformation ways of these examples has been experienced during the biennial and the boundaries of

architecture related to creation of public space and usage has been questioned.

2. Aims and Objectives of the Research

This study aims to question an architectural theoretical knowledge within a platform for experimentation, to discuss the functionalization of the boundaries of architectural criticism in various disciplinary fields, language and means of expression beyond a theoretical environment. The positioning of the works and presentations exhibited in public environment in the sampled architectural biennials, resulted in presenting problems and ascertains related to architecture and urbanization in an indirect way of cultural evaluation and criticism. The examination and interpretation of these presentations allow the architectural criticism to take part in various disciplinary platforms using indirect forms of expressions, to understand its effect and boundaries and to evaluate. Instead of studying and discussing the titles among the various themes of the Biennial directly or within their own disciplinary fields, this study aims to measure the contribution of these titles as visually represented in public spaces and their usage in disciplinary fields as a form of criticism and knowledge. Rather than the social effect of these individual works, this article concentrates more into understanding the continuity between the discussion topic and visual representation and the highlighted conceptual background of these works. Likewise, the boundaries of other neighboring disciplines to architecture such as art to be used as a platform of architectural criticism are also discussed. The study in this sense carries the samples collected from the installations exhibited in the biennial into the arguments within architecture and urban research and with these arguments, questions the continuity between the abstract and visual expressions. The main purpose is to uncover the power of sustainability of the works in biennials, recognized rather as an artistic event in popular culture, via abstract and theoretical exercises and to discuss the boundaries of non-verbal architectural criticism to be executed in various disciplinary platforms.

3. Biennials as a Criticism Platform

The urban space represents integrity not just with its physical attributes but also with its social, sociological, and psychological aspects. In urban space, the streets and squares are organic parts of the society. Humanity since the antiquity needed these squares, gathering areas, common spaces in order to escape the turmoil of city life in all cultures, and to meet, discuss daily problems, relax and to rest.[1]

The technological, financial, social and cultural transformations that we live through, effect

simultaneously the definition of public space and it transforms from being just a physical space into a media and digital environment shared by communication networks and free from its geographical attribute.[2] On the other hand, the urban and architectural identity standing out in the consumer society and considered as a marketing tool, develops a new public space that is first of all 'validated in diversity', context-free and unattached. For example, shopping malls popping up almost in every region, rather being just a commercial structure, appear to be alternative semi-public places.[3]

Furthermore, certain physical spaces that do not fall within the traditional definition of public space in terms of their size, dimension and structure typology, may obtain a public space character by sheer density of use and therefore interrupt the traditional representational relationship between architecture and public space. Due to new consumption behaviors, urban spaces become not just static physical locations but dynamic and receptive environments which can be re-defined by events. As a result, not just buildings but the flora, urban furniture, statues, events, installations become elements composing the public space and articulated with the structural infrastructure. Events such as exhibitions and biennials can be effective on this spatial transformation and re-definition process. The difference between the exhibitions, biennials and the traditional events is that they use the urban space as infrastructure and can initiate a process of criticism and transformation for that particular space.

The first architecture biennial organized in the world is the Venice Biennial in 1895. The earlier attempts of the Venice Architecture Biennial mainly focused on decorative arts and only in the first decade of the 20th century it gained an international scope. It can be observed that the international exhibition which began to take place from the year 1980 on began to look for understanding the impact field of architecture. Except for the first four exhibitions curated by Paolo Portoghesi and Aldo Rossi where the impact of the biennial on the international community of architects was not year entirely clear and beginning with the exhibition in 1991 when the national pavilions were first set up, there is a clear tendency towards conveying the audience more than architecture itself through main themes that refer to the city and the urban space with the help of rather stimulating and impactful contributions which put context and process to the forefront. This tendency became rather obvious especially throughout the exhibitions starting with the edition in the year 2000.[4]

The curator of the 14th exhibition on 2014, the internationally renowned architect Rem Koolhaas emphasizes this tendency and chooses to embrace the motto "Architecture, not Architects" in order to reduce the expectations from architecture and what it can refer to, but the will to focus on architecture itself. Koolhaas explains

the processes and phenomena he would like to focus on with his claim "Without the balcony, the history of the world would have looked completely different", referring to many political breaking points in history where the balcony was a critical spatial tool in conveying a message to the masses. By labeling the theme of the exhibition "Fundamentals", he denotes his wish to utilize the biennale as a space for discussing architecture itself instead of a showroom for star architects and their products. The following exhibitions in 2016 and 2018, the Venice biennale again focuses on topics which focus that deal with the larger field of impact on the architectural discipline.[5]

The Rotterdam Architecture Biennial is another example which has also proved itself to be of significance although it certainly does not yet match the impact of its counterpart in Venice. Its ambition to mirror the topics dealt with at the Venice Architecture Biennial failed at most times due to the fact that its international scope was rather limited and the extents of the exhibition in terms of space and participation were restricted. The Rotterdam Biennale is now held only in every four years and struggles to create the impact it originally wished to achieve.

Within the same time period, the extensive structural development and property investment in Southeast Asia and the Emirates moved the focus away from European cities as the main stage for architects to prove their worth, which also moved the debate on architecture further east to these geographies. The exhibitions organized in Shenzhen, Hong Kong and Seoul are clear demonstrators for this trend. At the same time, in addition to the architecture biennale held in Sao Paulo, the Chicago Architecture Biennial which began in 2017 managed to gain plentiful attraction.

Observing the selected themes and debates, it is possible to identify a political and philosophical attitude both in art and architecture biennials. Actually, the process is perceived as contradictory by most artists, and it is believed that globally biennials organized with the financial help of many international companies use art as an instrument to achieve their own goals. However, the most significant achievement of biennials thus far is the integration of art and architecture into the daily life of the city they are organized at and the fact that visitors can experience the works of many well-known artists and architects, follow the debates within the themes and participate during the biennial.

The architecture biennials should be considered as a critical platform, trying to understand the incidents within its professional area beyond the boundaries of singular representation of the work, creating alternative evaluation grounds by carrying the priorities in the selected themes to various other disciplinary arguments. So the works at the biennials aim to discuss the knowledge developed in other disciplinary fields by using the exhibition or expression

forms in a disciplinary multiplicity and interpreted the architectural work multi-dimensionally.

Demetri Porphyrios defines the architectural discussion as “a form of representation ignoring some definitions for the purposes of the dominant power relations and legitimize the current situation”.[6] In this respect, biennials and similar events should be considered as a ground of questioning the existing architectural discussion and generating alternative definitions and arguments for criticism processes.

Moreover, Tafuri underlines the problems arising from recognizing architecture just as a constructed environment and considering it only within its own disciplinary field and he emphasizes on the importance of looking into architecture from outside. Therefore, biennials create a platform to look into architecture from outside and just like Tafuri emphasizes, the architectural criticism, contributes to the efforts trying to eliminate the distinct boundaries between theory of architecture and history of architecture.[7]

3.1. International Architecture Biennial Antalya (IABA)



Figure 1. Experimental Architecture Works / IABA 2011, IABA 2013, IABA 2015

Currently in Turkey the architectural environment is far away from all these variety and wide range; the vision towards the city and architecture is defined on the scale of the individual work or what professional priorities define, the relations between architectural quality, philosophy and art is considered as a luxury currently out of discussion. Thereupon, The Chamber of Architecture of Turkey, Antalya Branch in 2001 came with the idea of organizing an Architectural Biennial in Turkey and realized the first International Architecture Biennial Antalya (IABA). The purpose was to reveal the approaches that contain some unique differences arising from the physical, cultural and traditional characteristics of this geography in use of public space.

In the same context, the first International Architecture Biennial Antalya was organized under the theme “Kesişmeler (Intersections)” the second one was themed as “Şablon (Pattern)”, the third one was “Geleceği Düşünmek (Thinking of Future)” and the fourth one was themed as “Süreklilik (Continuity)” in order to strength of the relationship between art and architecture over the city and its inhabitants through exhibitions in public space. Moreover, the International Architecture Biennial Antalya not only brings forward a conceptual and theoretical approach to the architectural profession, but it also

involves in architectural and spatial applications within “Experimental Architecture Works” concept and contributes to the profession by generating a platform for the bringing up new architectural arguments. The ultimate goal for the International Architecture Biennial Antalya is for it to become a clear part of the urban culture by providing a platform to initiate discussions on architecture and the city through experimental works by architects as individuals or groups with contributions from all related disciplines, exhibited at critical spots within the city that interact with the place.

“Most of the installations which become part of the daily routine or part the context they are located in, allowed for the urban space and the architectural works related to it consumed daily and habitually by users or audience, to be perceived in a fresh and different manner and create alternative relationships with them. Another important observation is that almost all of the outcome was built in a qualified and well thought manner within international standards from content generation to construction. When considered as a whole, as a result of architecture and the natural effects of daily culture emerging from consumption behaviors in the city, we are alienated to many facts in the city which accepted as value and so we observe an effort to question our way of living, the consumption of the city and to create alternative perceptions and awareness”.[8]

As an important part the Biennial, the “Experimental Architecture Works” strongly interfaces with the city and its inhabitants include installations which particularly emphasize the philosophical, artistic, cultural and critical qualities of the architecture. The building process in experimental architecture exceeding the traditional forms of understanding focuses on spatial practices by developing a vision which questions the systematics of existing rules and plans. This is actually where the design creates its own content. Although the aim of these rules and sequences is to ease our lives, this situation provides an opportunity or even sometimes a need for designers to see out of the box.[9]



Figure 2. Alisan Cirakoglu, Experimental Architecture Works / IABA 2015 (Photo: A. Cirakoglu)

Being experimental requires building new forms as well as analyzing issues from a fresh perspective. Nonetheless, during experimental works, the spatial examination, configuration and a user experience that evolves beyond the control of the architect/designer create diversified judgments. The aim in these works is to make the act of practicing architecture become tangible within public space, and to have the profession recognized transparently and experimentally through temporary spaces.



Figure 3. Experimental Architecture Works / IABA 2017

4. International Architecture Biennial Antalya as a Criticism Process: Understanding Architecture and Urban Relations through Experimental Architecture Works

In order to illustrate the discussion within the scope of this study, the ‘Experimental Architecture Works’ section, which constitute the main axis and the base for interpretation of the International Architecture Biennial Antalya, are being discussed. While staying within the main theme of the biennial, the differentiations in the relationship of these works with the theme and the city depending on the comments and expression techniques of the artists are open for evaluation in platforms with different priorities and discussions. Accordingly, architectural criticism tries to evaluate the styles of the architectural work and the physical environment to be shaped under the influence of multiple inputs and the

representational relationship of these inputs with the physical environment.

The example works chosen here were analyzed in subchapters following the biennial themes and representing the issues that exist within the architectural discourse. Additionally, they were evaluated by the discussion topics according to their forms of feedback. Obviously, these installations within their richness of concept and definition forms are open to be related to many subtitles and discussion frames. The main target is to sample these installations in the form of relating to biennial theme, rather than just understanding within their richness of definition. The installations should be considered as public use and open to various effects and inquiries, and they have to be comprehended. This study focuses on their expressions on contextual continuity / conflict, awareness, belonging and identity, cultural representation / daily life, symbolic value, and critical representations that are developed via discussions within the main theme and the entire biennial. From this point of view, it would be possible to consider the biennial installations being more than just independent artistic activities but also as part of a critical process, a form of definition related to different disciplinary fields.

4.1. Contextual Continuity / Conflict

International Architecture Biennial Antalya, as an input to its authentic physical, climatic, traditional and historical structure, has used a significant part of the experimental installations to question the contextual relationships or means of representation. Almost all of the biennial themes developed over the years are the basis for discussing problems related to the contextual relations observed in the physical urban texture. The fast urbanization process in Turkey and the typical construction styles of the global culture that we are part of, cast out the authentic architectural understanding which relates to land in a multi-dimensional way. The concept of “placelessness” constitutes the dominant face of cities. The concept of “critical regionalism” which was emphasized by Frampton for a contextual and land sensitive architectural view has become the starting point of most of the presentations and works.[10] For this reason, a part of the installations is composed of samples which relate directly with their surroundings or spend effort to transform and redefine it.

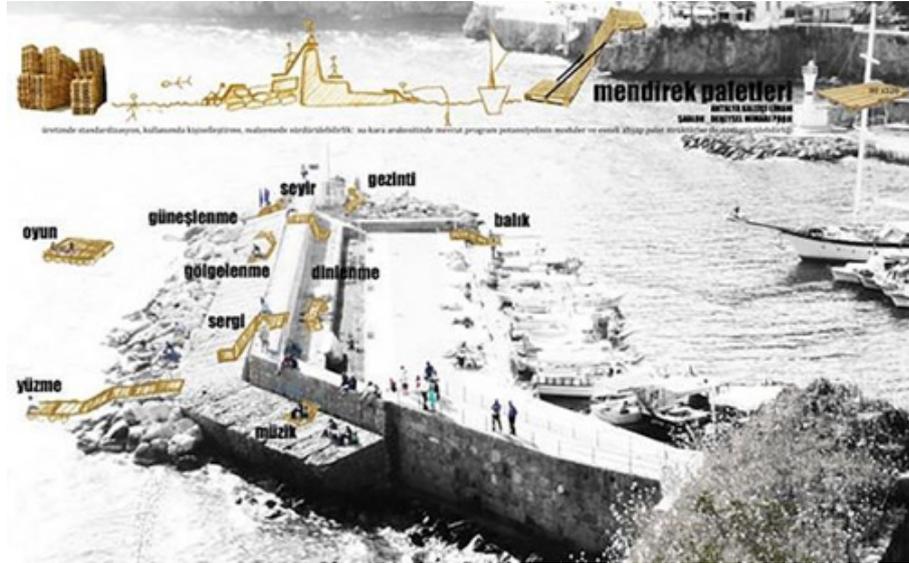


Figure 4. Palettes of Jetty, Defne Onen, Experimental Architecture Works / IABA 2015

The “Palettes of Jetty” created by Defne Onen can be considered within these examples. This work aims to question the recognition of construction, space, object, material, public space patterns. The logistics euro-palette which essentially designed for standardization has been carried alongside the jetty of Antalya Kaleici to create an alternative field and representation on existing environment. In a way, the work gets its meaning through the relationship built between location and the context and transforms its context by building coherence with it.

The area where the installation is located has lost its historical function of being a shipping port, industrial and commercial area and socio-economically been transformed into a touristic area instead. Within this transformation the palette material, which is in fact not foreign to this zone, is redefined by carrying a new function for consumption of the area. The architect Defne Onen describes the work as “a range of indoor-outdoor spaces, defined by the walls of the jetty, with a view towards the city, to old town harbor, and away from the city, to the sea and Taurus mountain range beyond”.

The installation composed of a range of lightweight structure, emphasizes, simplifies, interprets and diversifies the social behavior habits existing on densely populated pedestrian routes. The palettes while constitute relations between different elevations, inhabitants, land and sea they also contribute to the relationship between body and space and offer new functions related to the dynamics of space for its users. The spatial experience created by the installation, which is in continuous relationship with the context, strengthens the meaning of the context and also transforms it within its own dynamics. Placelessness, and to re-function a material used for displacement to establish a relevance with the location, has a direct contribution to architectural discussions of location and context.



Figure 5. Alveosis, Nilufer Kozikoglu & Urban Atolye - Experimental Architecture Works / IABA 2017 (Photo: Erdönmez, M. E.)

Alveosis is an experimental work carried out by Urban Atolye, which was established by Nilufer Kozikoglu as a result of her works on material- and structure related research and design. Alveosis is an installation in Karalioglu Park resembling the bones of a giant creature or a giant root. It is a tubular network of branches with holes and contains a living organism in its holes. Alve means ‘with holes and cellular’ and is a derivative of the word alveolar. Alveosis emphasizes the formation of phases of cellular structure. Being a part of the Nilufer Kozikoglu’s material and structure research with the name Alve, the work is created by spraying concrete with added fiber on fabric mold with the support of Fibrobeton.

Besides the structural attributes of the installation with its caviated and continuous network, the design includes mushroom seeds mixed with wood shavings stuffed into the structure. It provides an opportunity to observe how the structure would react or harmonize with the other organisms surrounding or interacting with it. The designer presents to its architectural audience, a research summarized as biophilic design where the organic and nonorganic can commonly exist in continuity. It has been observed that the design transforms the location it interacts with and also re-defines it with its own existence.

4.2. Awareness

Within the process of urbanism, together with the definition of “placelessness”, another often discussed term “alienation” means the loss of the mental continuity relation established with the land. Bauman defines the concept of “alien” in social life as being physically near but mentally distant.[11] Within the post-modern culture, we have difficulties in establishing a critical and semantic relationship with many urban phenomena that we are physically related to. Especially the consumer society culture aims to approach our environment in reduced and uniform classifications and to liquidate their exclusive diversity. Antalya and especially the biennial district, has many authentic and multi-defined physical settlements together in historical layers. Within the daily flow and restrictions of social culture, we cannot establish a reasonable awareness relation with most of the elements in this environment. As Bauman states, we cannot carry our physical proximity to mental dimension. A part of the works in the International Architecture Biennial Antalya, aim to carry the physical and visual relationship established with the city to an awareness process and in a way to create a critical perception.



Figure 6. Bakanak, Bogachan Dundaralp, Experimental Architecture Works / IABA 2011 (Photo: Erdönmez, M. E.)

The “Bakanak” installation in Experimental Architecture Works, located at an axis with an intersection of different historical layers. The installation, which was located at the central refuge on the road between the Gate of Hadrianus and the Karakas Mosque, guides the visitors to observe the surrounding buildings explicitly once inside.

In this respect, the design creates awareness towards its location and the city, and establishes a physical and visual relationship. The climatic conditions effected the selection of the material; the natural wood was used to attract the attention to the fact that wood is not sufficiently used although expected to be so considering the climatic conditions of Antalya. The main purpose of this installation is to create awareness by attracting attention to selected multi-layered focus points that city has generated and again create a sense of belonging with the individual meanings of the elements.



Figure 7. Intersect, Fikret Sungay, Salih Kucuktuna, Guvenc Topcuoglu - Experimental Architecture Works / IABA 2011

The “Intersect” project located in public space belongs to Fikret Sungay, Salih Kucuktuna and Guvenc Topcuoglu. As a starting point for the design they considered the interaction of architecture with the people living in and got inspired by the organic/dynamic pattern of the Antalya Old town district, which was formed by the social life, traditional architecture, history, climate, geography, multi-cultural structures and many other parameters. The project provides an impression of an Old town street, gained significance with the axis created, as a tectonic structure and typology, the dynamic structure in its geometry, its material, all intersect in a triangle of modern life, existing organic historical street structure and human perception.

4.3. Belonging and Identity

Although globalization redefines the physical environment in the modern society through production and consumption processes, social life forms are

becoming independent from geographical differences. This tendency enforces uniformity which in turn deteriorates the feeling of belonging and the intimate relationship of person to a place, and the values of identity established with culture through place. David Harvey defines post-modernism as “the cultural logic of late capitalism” and emphasizes the standardization effect of the new flexible production processes against the geographies.[12]



Figure 8. Not Here, Ahmet Onder, Ceren Balkir - Experimental Architecture Works / IABA 2011 (Photo: Erdönmez, M. E.)

The work exhibited at the biennial with the title “Not Here” aims to recreate identity through an installation that is not only foreign to its location in the city but also to the typology of urban furniture around itself. It serves as a pit stop which establishes a specific relationship that place and a sense of belonging between the user and the place. The work was installed within a crowded pedestrian zone in the city, as a standalone element within a foreign morphology.



Figure 9. Half-time, Cengizhan Aydin, Tugce Sahin - Experimental Architecture Works / IABA 2011 (Photo: Erdönmez, M. E.)

The city and especially the public space have always been a place where inhabitants from various cultural backgrounds can meet. It is an urban space for individual

and group activities bound by commonly accepted rules and reflecting the needs of its users. In the work “Half-Time”, the designers aim to observe the physical environment by disconnecting from the place, its habitual and known context, to re-route the conventional usage of the location and so establish a belonging feeling between the place and the individuals. The design offers the possibility to spend time on the pavement, to stop, to play and to have fun rather than just to walk or pass by.

4.4. Cultural Representation / Daily Life

Every object in the built environment has a representation value together with its functional value, and the physical environment is associated with everyday life in various scales, densities and priorities. Jean Baudrillard mentions that a post-modern world emerges within in pop-cultural environment with the effect of media and choices of the consumer society, where everything is reduced to “representations”.[13] In daily life the relationship we establish with city and space finds meaning and value mostly from this reduced representation whereas the awareness and originality that the critical culture may create are usually hidden. In most of the experimental works at the Biennial, it is possible to observe an effort to transform this reduced representation value to a critical awareness.



Figure 10. Anti-gravity, Ebru Erdönmez, Burak Haznedar - Experimental Architecture Works / IABA 2011 (Photo: Erdönmez, M. E.)

The project “Anti-Gravity” aims to define the way of designing a space or a form without gravity create volumes that cannot exist in everyday situations, with the help of easily found casual objects. The layers of the volume and its space as an emptiness by creating intersections of before and after’s, piling up the elements within this association, carrying it away from its daily meaning and establishing new forms. The work created by generic tools like balloons and a net, provides an opportunity to re-constitute spatial relationships in a dynamic way, each time with a new user. This unusual and dynamic space questions the perception of daily

'admitted' spatial representation and habits.



Figure 11. Common-action Walls, POT+, Fulya Ozsel Akipek, Tugrul Yazar, a.o. - Experimental Architecture Works / IABA 2017 (Photo: Erdönmez, M. E.)

Likewise, in the project "POT +" uses two separate elements together carrying static representation values in modern life; a wall and vegetation. The wall hosts plants through the holes that provide space to cultivate vegetables. "POT +" is the structure of cultivation, nursing and harvesting plants continuously, sustainability and works as a participatory urban garden idea. The team investigates forms and materials before the construction phase and by modelling the Gyroid network in a digital environment which provides the water flow from fluidal surfaces of the wall, they created maximum light and air flow and space for the plants. Supplementary elements such as lime and acrylic mixed, compressed and shaped with traditional soil and so the limits of its usage in daily city life was questioned. This experimental installation sends a message to environmental sensitivity while opening the representative values of habitual elements to discussion.

4.5. Symbolic Value



Figure 12. The Cube, Ekmel Ertan - Experimental Architecture Works / IABA 2013 (Photo: Erdönmez, M. E.)

Likewise, Baudrillard emphasizes the importance of symbolic value in consumer society culture and underlines the market value through from the symbolic values of objects. In modern urban environment, all objects, particularly the buildings, besides their functional values gain meaning with their symbolic values and even sometimes these meanings go ahead of their functional values.[14]

The Project "The Cube" is a public art project, a statue and a virtual gallery. Using a conceptually reversed (inside-out) metaphor gallery, the cube is a symbol representing the project itself. The codes at three sides of the cube connect the audience via smart phones to a virtual gallery and become the symbol of the gallery at the street.

The virtual gallery establishes an online network via cubes located in various cities of the world. Each cube takes the audience to different rooms of the virtual gallery. The (TODAYSART)3 takes the audience to the virtual halls of Today's Art Festival in Lahey and the (ISSYK-KUL)3 to the halls of Bishkek Contemporary Art Center. It also takes the audience coming from The Hague and Bishkek to the halls of Antalya Biennial. The audience has to carry a mobile phone in order to view the work of arts in virtual gallery that the Cube is connected to. When they take a picture with a free application to read a QR-code they reach to the connected halls of the gallery and can watch or listen the works exhibited. In time, the cube transforms into an urban symbol representing art.



Figure 13. Sea³, Alisan Cirakoglu - Experimental Architecture Works / IABA 2011 (Photo: Erdönmez, M. E.)

The project of Alisan Cirakoglu; "The Sea³", interprets the concept of fullness - empty, one of the main topics of architecture, on the basis of the relation of Antalya with water. Installing the work in an empty space, the architect created gaps that people can fit in and thus desired to establish a physical relationship between people, architecture and biennial. As a result, we see that besides offering an abstract discussion and a landmark, the place itself becomes a symbol that can be redefined.

4.6. Critical Representation

The experimental works taking place in this study

involve a complexity open to be understood and evaluated in a variety of references. The common platform in which all these samples gather is the critical representation value they involve in various perspectives. It is an effort to observe the incidents around us, by providing reference to the city, the physical and natural environment, as well as various discussion frameworks from a critical distance and to re-define them all. Some examples use the language and tools of art intensively and some others prefer to stay in conceptual frames where the audience is pulled in. In spite of all these differences, it is possible to read the biennial installations as a critical text and observe the transmissivity between the dissimilarities of cultural platforms as a definition on architectural criticism.[8] Most of the works carry characteristics of an art object involved in daily life and also represent discussion or parallel values which can only be gained through know-how and effort. In this sense, it targets daily users and also various disciplinary studies and references. Similarly, like Benjamin underlines, in the post-modern era, the objective production and the intellectual production establishing its background, are joined and the art piece performs a critical functionality. [15]



Figure 14. Local 2.0, Selcuk Kismir, N. Gokce Tufekci - Experimental Architecture Works / IABA 2017 (Photo: Erdönmez, M. E.)

Some of the works present relatively open and critically direct texts actually bring topics, concepts and researches that are not commonly discussed an everyday life into the daily life and to public space. The project “Local 2.0”, examines the concept of sustainability which was generated by the economic, political and cultural transformation after 1980’s. In this sense, the research aims to present a detailed matrix which analyses the actors and elements integrated into a construction in anywhere in the world, and to the process of establishment of that construction. While revealing the global designer, contractor and supplier network which create a single construction, referring to the same players and holding the traditional sub-locals at the background, it provides an opportunity for a double-sided reading.



Figure 15. Between the Walls, Ferhat Hacialibeyoglu / IABA 2013

The “Four Walls” project which forces to think the concept of template itself, with a critical approach, underlines the question of how the form and design becomes a compulsorily template.

Table 1. Experimental Architecture Works

Contextual Continuity Conflict	Palettes of Jetty	Alveosis
Awareness	Bakanak	Intersect
Belonging & Identity	Not Here	Half-time
Cultural Representation Daily Life	Anti-gravity	Common-action Walls
Symbolic Value	The Cube	Sea ³
Critical Representation	Local 2.0	Between the Walls

5. Conclusions and Arguments

This study discusses two fields within a relationship. First, biennials as a cultural platform for criticism, is more specifically the relationship between the architecture biennials and architectural criticism. Second, the representation forms and boundaries of the architectural culture and criticism especially in artistic and other disciplinary expressions.

In general, biennials, especially the architecture biennials, besides their interpretations of extensive activity have to be perceived as an alternative criticism environment, a critical process. The works in the International Architecture Biennial Antalya sampled in this research question perception and problems directly related to architecture and city within frameworks defined by modern day architecture problems and also provide a critical view to these problems not just limited to disciplinary boundaries. This approach which is especially discussed over Experimental Architecture Works functionalizes various disciplinary content and demonstration. The biennial exhibitions not only emphasize problems that we are accustomed to within the city and not aware of in daily life, they also represent an effort to reflect these problems to inhabitants and create awareness. Architecture when perceived in various other fields than its own profession; such as culture, politics, sociology, economy, history and art and when opened to discussion through alternative ways of expression which involve the presentation styles of these fields, the representation environment of the current power relationships and being more than a legitimization process, can be opened to new awareness and establish a real critical platform. Biennials in this respect should be considered as an alternative to inured forms of value generation and be perceived as critical platforms questioning and trying to reverse the legitimization processes.

The city is a collection of multi-layered relationships and the sustainability of the urban idea can only be possible by the participation of all players represented within these relations. Another contribution of the biennials is that they carry a potential of creating awareness by attracting a critical process not only by the certified actors in creation of architecture or art but also the other actors who also claim the space.

Considering all these observations, the International Architecture Biennial Antalya tries to actualize an alternative awareness mechanism for Turkey where especially the urbanism problems accelerate to become more serious and also tries to include the local inhabitants and the actors consuming the physical space into a critical process. One of the originalities of the International Architecture Biennial Antalya is the effort to relocate the exhibitions into public spaces and the sustainability relationship established with the city and its context. Like

in many artistic work or biennials we should not expect a direct, solid, practical reflection and result from this example.

However in societies especially where the critical culture is missing and the architectural and urban criticism has not been institutionalized yet, the existence of these kind of critical platforms and to sustain them becomes vital. The biennial know-how introduces a rich data open to evaluation for various frames and new works. All these works directly or indirectly will contribute to the establishment of a critical architectural culture.

The argument, in which the study forms an experimental framework with examples and concentrates in more detail, emphasizes the continuity between art and architecture. In most of the examples discussed here, the installations with highlighted visual effects are in the form of an abstract critical expression. These expressions when perceived in continuity with the contextual architectural arguments, in parallel to their visual presentations, are a critical text open to various interpretations. It is obvious that in daily life with different users involved, one cannot expect these works which are associated with biennial theme and architectural discussions, to be perceived in the same way of representation, reference and clarity. It is not the direct aim of the biennials and the installations or exhibitions they hold, to create a representation which competes to texts or academic lectures generated in disciplinary communities. The biennials especially like the International Architecture Biennial Antalya which infiltrate into daily life and to urban areas aim to create awareness towards the physical environment and to urge some questions to be asked rather than to make a direct critical evaluation for everyday consumers. However, the biennials should be considered as a sustainable argument and evaluation environment regardless to its own product and exhibition period. In this respect these kinds of similar studies should rephrase the biennial exhibitions in disciplinary frame either individually or as a whole.

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Bending Behavior on Beam with Supporting Part

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Abstract Equipment used to help road users during road maintenance activities is called a flexible bridge. It helps maintain the accessible area of the road when repairs occur. Collapse has occurred sometimes at frame when bending load exceeds the yield strength. In addition to increase the ability of the structure and avoid buckling added a link as damper. Parameters of the absorber are stiffness rate, and elongation of link. A simple square tube beam model supported by a link was created to investigate the bending behavior using finite element analysis. The analysis result showed that beam supported by a link able to reduce buckling moreover provides longer curvature than beam without a link.

Keywords Flexible Bridge, Finite Element

1. Introduction

Nowadays many structural members are composed of various types of tubes. Rectangular tube is one of the commonly referred as supporting structure. Many researchers have studied experimentally and virtually using finite element about characteristic of deformation on rectangular tubes [1]-[4].

Plastic deformation of collapse mode on rectangular tubes was theoretically explored [1]. Kecman proposed a simple collapse mechanism using hinge moment and associated angle of rotation. A new collapse mechanism of rectangular section columns improved Kecman's theory

[5]. Axial compression of rectangular tube obtained as complex deformation mechanism around tube's web [6].

Numerous finite element analysis of rectangular tube to explore plastic deformation investigated widely [7]-[9]. Buckling behavior was observed as critical problem caused structural ruptures. Buckling was observed from flattening ratio which influenced most by geometrical shapes rather than material properties [10]. Flattening deformation influenced by ratio of thickness, length, and width of sidewall [8].

Supporting structure to increase buckling resistance of tube subjected to axial crushing and lateral bending was developed in many applications. A foam-filled thin-wall tube with various lateral graded thicknesses was applied in automobile components [11]. Due to localized deformation, the buckling resistance decrease sharply. Foam material was acting as support against buckling [12].

This study was focused on square tube structures using link as supporting part to reduce buckling. Supporting part was attached on end side of tube and fastened to rigid wall while the other side received bending momen. Elongation of supporting part investigated to observed buckling resistance of whole structure.

2. Methodology

Research model of square tube for bending analysis was built from thin-wall structure. Tube thickness t was varied at web and the lid thickness t' set to five times of t [13]. Dimension of C1 and C2 are equal to C (100mm), Figure 1 shows the square tube model.

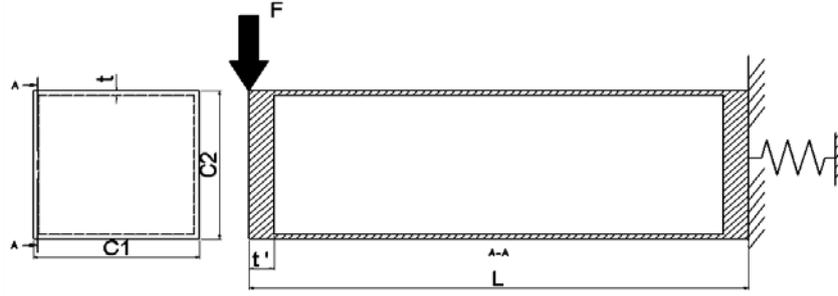


Figure 1. Square tube model

Material of square tube assumed bilinear isotropic hardening in uniaxial stress. Properties of stress-strain relationship followed rule (1) for elastic condition and rule (2) for plastic condition according bilinear law.

$$\sigma = E\varepsilon \quad \left[\varepsilon < \frac{\sigma_y}{E\varepsilon} \right] \quad (1)$$

$$\sigma = \sigma_y + Eh \left(\varepsilon - \frac{\sigma_y}{E} \right) \quad \left[\varepsilon > \frac{\sigma_y}{E} \right] \quad (2)$$

Parameters and material properties of square tube are followed table 1

Table 1. Properties of square tube

Properties	Value
Length [L] (mm)	1000
Width [C1=C2] (mm)	100
Thickness [t] (mm)	2
Modulus [E] (GPa)	205.9
Poisson's ratio [ν]	0.3
Hardening ratio [Eh/E]	1/100
Yield stress [Y] (MPa)	205.9

Supporting part characteristic is according to figure 2.

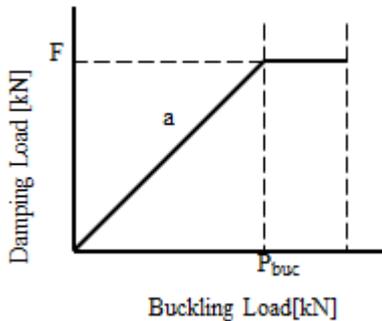


Figure 2. Supporting part characteristic [11]

Supporting part's characteristic is followed equation (3). This is assumed to be spring force according to Hooke's law.

$$F = a P_{buc} \text{ [KN]} \quad (3)$$

$$P_{buc} = \sigma_{buc} \cdot A$$

Table 2. Supporting part parameters

Parameter	Value
Stiffness rate (a)	0.2, 0.4, 0.6, 0.8
Shape factor (t/C)	0,02

Where F is damping load of supporting part, P_{buc} is buckling load at square tube, and A is rectangular cross section of square tube.

3. Result

Finite element modelling was made by MSC Marc software to conduct analysis of bending square tube. Meshing type is quadrilateral, where 1 element consists of 4 nodes, element type of tube is 3D shell. Meshing size is 5x5 [mm]. Maximum bending stress obtained from table 3 for square without damper and square tube with supporting part.

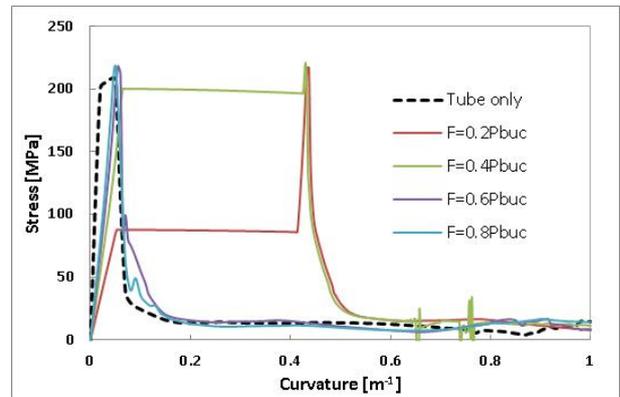


Figure 3. Bending stress comparison of square tube due to damping load of supporting part

Table 3. Bending stress comparison

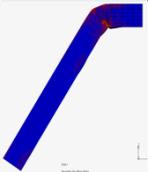
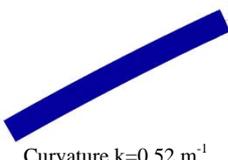
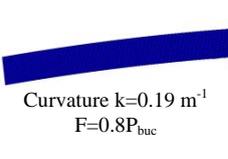
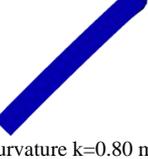
Damping Load F=[kN]	Max Bending stress [MPa]	Curvature [m ⁻¹]
Square tube without damper	208.034	0.040
0.2 P_{buc}	217.09	0.433
0.4 P_{buc}	220.86	0.430
0.6 P_{buc}	218.44	0.055
0.8 P_{buc}	218.14	0.050

From table 3 maximum bending stress obtained at square tube without supporting part and smallest curvature obtained from square tube with damping load $0.8 P_{buc}$.

Result of bending on square tube also obtained as image from each curvature condition as seen at table 4. Each damping load produces different deflection and buckling point.

Another result to analyse bending characteristic of square tube is elongation of the supporting part. Figure 4 described elongation and curvature from each damping load.

Table 4. Square tube condition base on damping load

Visual Deflection	Visual Buckling
 <p>Curvature $k=0.19 \text{ m}^{-1}$ Square tube only</p>	 <p>Curvature $k=0.80 \text{ m}^{-1}$ Square tube only</p>
 <p>Curvature $k=0.19 \text{ m}^{-1}$ $F=0.2P_{buc}$</p>	 <p>Curvature $k=0.80 \text{ m}^{-1}$ $F=0.2P_{buc}$</p>
 <p>Curvature $k=0.19 \text{ m}^{-1}$ $F=0.4P_{buc}$</p>	 <p>Curvature $k=0.80 \text{ m}^{-1}$ $F=0.4P_{buc}$</p>
 <p>Curvature $k=0.52 \text{ m}^{-1}$ $F=0.6P_{buc}$</p>	 <p>Curvature $k=0.80 \text{ m}^{-1}$ $F=0.6P_{buc}$</p>
 <p>Curvature $k=0.19 \text{ m}^{-1}$ $F=0.8P_{buc}$</p>	 <p>Curvature $k=0.80 \text{ m}^{-1}$ $F=0.8P_{buc}$</p>

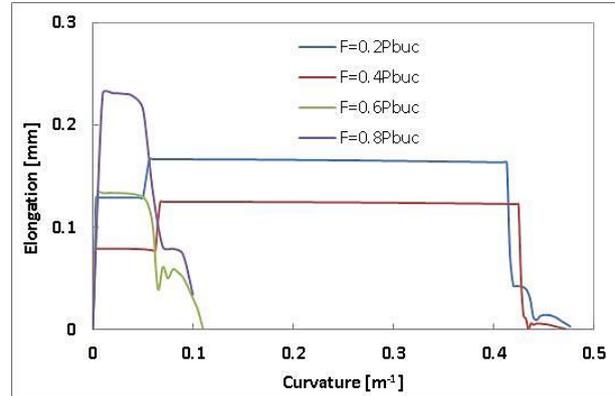


Figure 4. Supporting part elongation and beam curvature

From figure 4 square tube with $F=0.8P_{buc}$ is longest elongation and tube with $F=0.4P_{buc}$ is smallest elongation. While square tube only is considered as basic elongation (null) without supporting part.

Table 5. Maximum elongation of supporting part for each damping load

Damping load $F=[\text{KN}]$	Max Elongation [mm]	Curvature [m^{-1}]
Square tube only	-	-
$0.2 P_{buc}$	0.166	0.476
$0.4 P_{buc}$	0.125	0.472
$0.6 P_{buc}$	0.133	0.110
$0.8 P_{buc}$	0.231	0.100

Geometrical view of buckling point described at table 4. Buckling is happen at near end-side of square tube with supporting part, otherwise square tube without supporting part has buckling away from end-side of the beam. This condition explained from simulation model. Bending load attached at front side of beam, while bending rotation start load concentrated on all surface. Lower side of beam againsts compression stress so the buckling occurs at this surface.

Conversely beam with supporting part can share elongation between beam's surface and supporting part buckling occurred at near end-side of beam and rigid wall. Because of lid thickness of end-side 5 times higher than web, compression stress concentrated at lower side and buckling occurred at this point rather than rear end surface. Contact between supporting part and rigid wall attached at rear-end side.

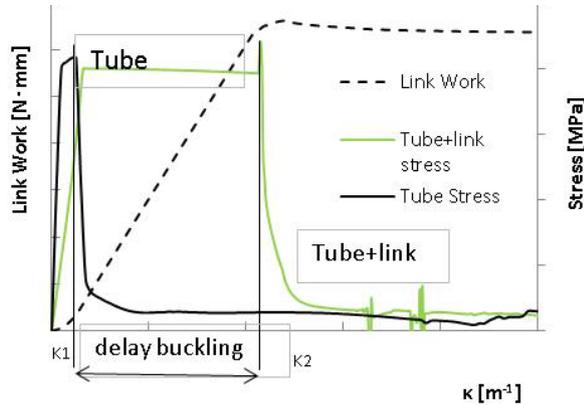


Figure 5. Stress comparison between tube only and with supporting part ($F=0.4P_{buc}$).

Figure 5 shows that square tube using supporting part occurred buckling at K_2 and square tube only at K_1 . Those points showed that using supporting part could increase curvature and reduce buckling than square tube without supporting part.

4. Discussion

According to result of bending beam it seems that tube without supporting part has lowest bending stress compare to others. It is happen because entire bending stress only restrain by it square tube body and directy contact by bending force. However this condition result high initial bending stress. Compare than square tube with supporting part, they led initial elongation between tube and supporting part. Produce lower initial bending stress and longer elongation. Square tube with supporting part $F=0.8P_{buc}$ has longest elongation.

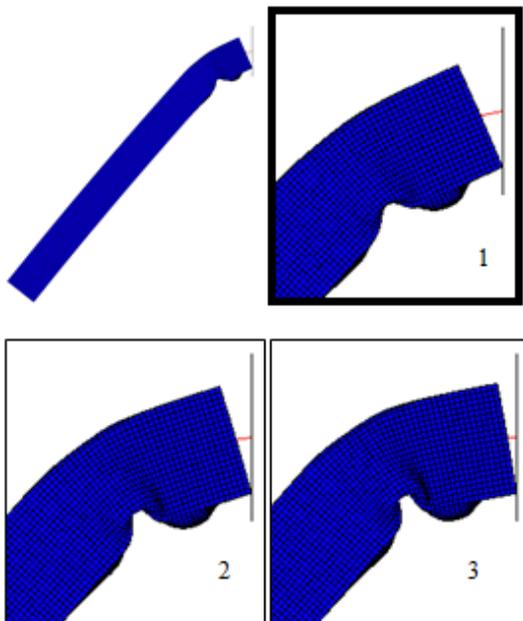


Figure 6. Buckling condition at $F=0.6P_{buc}$

Also we obtain from figure 6 the deformation of square tube with supporting part has unique form. Buckling point happen at near lower end-side of beam. This happen due to concentration of compression stress are accumulated at lower end of beam bordering with rigid wall, this could create buckling point at lower end-side of square tube.

Beam with supporting part are obtained increase the curvature and could reduce buckling when choosing optimum damping load. In this research optimum damping load obtained at $F=0.4P_{buc}$, maksimum bending load also obtained at $F=0.4P_{buc}$. This beam's setting could divide stress between beam and supporting part produce highest bending stress.

5. Conclusions

According to finite element analysis of bending on flexible bridge structure lead the conclusion of this study to:

- Buckling can be reduced by using supporting part which can increase buckling stress resistance of the beam.
- Buckling also obtained delay at longer curvature between beam only and beam equipped with supporting part.
- Supporting part in this research helps to explain characteristic of modified beam when experience bending momen. Supporting part related to spring or damper in structural application.

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Elderly Perception of Critical Issues of Pedestrian Paths

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Abstract Pedestrians aged over 65 are known to be a critical group in terms of road safety because they represent the age group with the highest number of fatalities or injured persons in road accidents. It is therefore important to identify and characterize how old pedestrians perceive pedestrian paths with respect to their age related declines in perceptual and physical abilities and with respect to their experiences as road users. The aim of this study is first of all to understand which critical issues old pedestrians found in the pedestrian paths they usually walk. More specifically, the final aim is to capture and analyze the key components that influence the elderly pedestrians' perception of pedestrian paths and to identify how these perceptions change for different pedestrian "profiles" based on human factors. The aspects related to human factors considered are the gender, the factors associated with the experience as road users and the factors related to age related problems (mobility, vision and hearing problems). The results show that the judgment expressed by the elderly on the critical issues of pedestrian paths they usually walk is significantly linked to gender, to their experience as road users, and to vision problem, which compromise the correct perception of the road environment. This is important to determine interventions and could support traffic engineers, planners, and decision-makers to consider the contributing factors in engineering countermeasures.

Keywords K-Means Cluster Analysis, Hierarchical Cluster Analysis, Survey, Road Safety, Vulnerable Users, Human Factor

1. Introduction

Deaths and injuries resulting from road traffic crashes is a serious problem globally and current trends suggest that this will continue to be the case in the foreseeable future [1]. According to the World Health Organization, the number of annual road traffic deaths reached 1.35 million in 2018, which is considered to be the eighth leading cause of death

globally [2].

Of the total 1.35 million people dying in road traffic crashes annually, at least 30% are in urban areas [2]. Pedestrians are considered the most fragile road users in the transport system. They are at maximum risk compared to any other road users because of their fragility, slow pace, and their absence of protection [3]. In Europe, the safety of a pedestrian has been problematic for a long time. The actions taken to reduce pedestrian crashes have been much less notable compared to those for the total traffic accidents, although the total number of fatalities has decreased significantly during the period 2006–2016. In the European Union, a total of 5320 pedestrians were killed in road accidents in 2016, 21% of all road fatalities [4].

The reality of an aging population, particularly in "economically developed" countries, has made the everyday mobility of seniors an issue of growing interest. In a context where an increasing number of people globally are dependent on cars, efforts to encourage walking - both utilitarian and leisurely - has become a public health priority [13]. However, public transportation and walking environments are not always well-adapted to accommodate the elderly. In order for walking to become an attractive, efficient, and safe mode of transportation for the elderly, the way public spaces are designed must be rethought/reconsidered in order to accommodate to their needs and preferences.

Age related declines in perceptual, cognitive, and physical abilities have been shown to result in non-optimal street-crossing decisions and behaviors [6, 7, 8] and may contribute to the high rate of fatal or serious-injury crashes found for old pedestrians [9]. Because of age-related perceptual, cognitive, and motor limitations, and in line with [10] as well as [11], old pedestrians are expected to experience more difficulty than young pedestrians.

Considering the above facts, it is important to identify and characterize how old pedestrians perceive pedestrian paths with respect to their age related declines in perceptual and physical abilities and with respect to their experiences as road users.

The final aim of this study is first of all to understand

which critical issues old pedestrians found in the pedestrian paths they usually walk. Moreover, this study seeks to analyze how old pedestrians' age related declines in perceptual and physical abilities (vision, hearing and mobility problems) and experiences as road user (no driving license, no still driving, accidents driving, accident pedestrian) can affect their opinion on the critical issues of pedestrian paths.

This is important to determine interventions and could support traffic engineers, planners, and decision-makers to consider the contributing factors in engineering countermeasures.

2. An Overview of the Literature

Walking is particularly important for the elderly, who are less likely than younger adults and children to participate in more vigorous forms of physical activity, more likely to experience social isolation and less likely to drive a car. Walking is also highly valued by seniors for a range of reasons, including improved health, wellbeing, independence, personal mobility and social connectedness. Moreover, walking is critical to allow older people to conduct day-to-day activities, such as shopping, attending meeting places (sporting clubs, libraries and community centers) and visiting essential services like doctors and hospitals [12]. In addition, in Italy 33% of grandparents take care of grandsons every day [13]. This makes increasingly important to create safe walking opportunities around schools, as the two most vulnerable road user types walks together [14]. Walking can also reduce transport-related costs, including lower personal expenditure on fuel and vehicle maintenance. These aspects can be critical for older adults, who generally have lower annual incomes and for whom transport costs may represent a larger component of their expenses. The combination of these factors can result in transport disadvantage and social exclusion, which has been identified as a significant problem facing older adults [15].

It is well understood that walking has significant physical health benefits for older people, including reduced risk of many chronic diseases such as obesity, heart disease and diabetes [12, 15]. A well-established finding in the literature is a link between physical activity and decreased risk of many chronic diseases [16], including cardiovascular disease in people of all ages [17]. When analyzing the vulnerability of older pedestrians, it is important to consider the impact of physiological and cognitive changes that occur as people age. The World Health Organization in its 2013 report "Pedestrian Safety - A Road Safety Manual for Decision Makers and Practitioners" states that the combination of the following factors increases the vulnerability of older pedestrians: deterioration in visual acuity results in older pedestrians accepting significantly smaller gaps in traffic than required

when crossing roads; cognitive decline results in reduced ability to make safe judgments about walking speed and traffic gaps; reduced mobility results in an inability to react quickly and avoid crashes; frailty and existing health conditions can result in greater injury severity when a crash does occur; slower walking speeds can result in older pedestrians being stranded in the middle of the road when attempting to cross at signalized crossings.

Ageing results in gradual deterioration of agility (walking speed and balance), sensory perception (vision and hearing) and cognitive skills (attention and information processing speed). Older pedestrians can thus experience problems in situations that demand efficient cognitive processing, fast responses and quick actions [18].

Age-related changes reduce people's ability to undertake the many cognitive tasks required when crossing roads, such as finding a place to cross a road, looking for traffic, perceiving traffic, judging vehicle speeds and available gaps, deciding when to cross and then crossing the road. Older pedestrians are over-represented in crashes at complex intersections (particularly those with two-way traffic and/or multiple lanes) and when traffic volumes and speeds are high.

Outdoor walking, as a type of physical activity, takes place in outdoor spaces. It has well-known benefits for health in later life and older adults are recommended to take outdoor walks [19-21].

Evidence indicates that neighborhood safety, pedestrian infrastructure and aesthetics are important for supporting and encouraging outdoor walking [22-26] because pedestrians move slowly in outdoor spaces thus affording the ability to notice route characteristics [27].

These built environment attributes seem especially important for older adults' outdoor walking [19, 28, 29, 30]. For example, older adults may avoid walking to available attractive destinations located in walking distances due to high risk of accident [29]. Evidence has shown that for older adults' outdoor walking, maximizing the neighborhood aesthetics or quality of pedestrian infrastructure is more important than minimizing the distance to a destination [29].

Zandieh et al. [31] examine inequalities in perceived built environment attributes (i.e., safety, pedestrian infrastructure and aesthetics) and their possible influences on disparities in older adults' outdoor walking levels in low- and high-deprivation areas of Birmingham, United Kingdom. It applied a mixed-method approach, included 173 participants (65 years and over), used GPS technology to measure outdoor walking levels, used questionnaires and conducted walking interviews to collect data on perceived neighborhood built environment attributes. The results show inequalities in perceived neighborhood safety, pedestrian infrastructure and aesthetics in high- versus low-deprivation areas and demonstrate that they may influence disparities in participants' outdoor walking levels. Improvements of perceived neighborhood safety,

pedestrian infrastructure and aesthetic in high-deprivation areas are encouraged. Most participants, particularly in high-deprivation areas, also talked about perceived uneven pavements, broken slabs, presence of potholes, cracks and obstacles (e.g., knocked down bollards) in pavements.

Kahlert and Schlicht [32] use an experimental study design with computer-simulated living environments to investigate the effect of micro-scale environmental factors (parking spaces and green verges with trees) on older people's perceptions of both motivational antecedents (dependent variables). Seventy-four consecutively recruited older people were randomly assigned watching one of two scenarios (independent variable) on a computer screen. The scenarios simulated a stroll on a sidewalk, as it is 'typical' for a German city. In version "A" the subjects take a fictive walk on a sidewalk where a number of cars are parked partially on it. In version "B", cars are in parking spaces separated from the sidewalk by grass verges and trees. Subjects assessed their impressions of both dependent variables. A multivariate analysis of covariance showed that subjects' ratings on perceived traffic safety and pedestrian friendliness were higher for version "B" compared to version "A". The study suggests that elements of the built environment might affect motivational antecedents of older people's walking behavior.

Many researches examine the perception of elderly pedestrians about the quality and risks of the elements that characterize pedestrian routes (e. g., sidewalks and pedestrian crossings) in various investigation contexts. In particular, Lord et al. [33] examines the case of road crossings in the context of Montréal, Québec, Canada. The analyze are based on observations and questionnaires in order to bring to light a better understanding of the relationship between the crossing behaviors, characteristics and perceptions of the elderly. Five profiles of elderly people in both urban and suburban environments were established. A sample of 181 elderly pedestrians (65–93 years of age) were surveyed using a questionnaire. In addition to close-ended questions, respondents were asked to evaluate 17 environmental ambiance and risk behaviors according to various scales. Using principal component analysis (PCA) and hierarchical cluster analysis (HCA), the data was grouped into 6 categories that define and distinguish 7 profiles of elderly people. These profiles were explored according to the socioeconomic status and crossing behaviors of respondents. The probabilities of adopting different crossing behaviors were tested by employing logistic regression models. The results reveal greater variability in the perceptions of the elderly in terms of risk related to crossing behaviors and type of signalization at intersections.

Noh et al. [34] have investigated common and diverse contributory factors to elderly pedestrian injuries, by segmenting the elderly into the younger-old (between 65 and 74 years) and older-old (over 75 years). By employing single and interaction binary logit models, the study

identified common risk factors for both elderly groups, as well as those that are particularly hazardous to the older-old. It was found that older age was the most critical risk factor leading to severe injury. A set of common contributory factors for both elderly groups was identified, including near overpass crossing, roadside, drunk, and truck. On the other hand, uphill, downhill, nighttime, and sidewalk were found to be a much higher risk to the older-olds.

Finally, a 2012 Belgian research [35] is particularly interesting for the purposes of this study. Van Cauwenberg et al. [35] sought to uncover the perceived environmental influences by elderly Flemish pedestrians. To get detailed and context-sensitive environmental information, it used walk-along interviews. Almost all participants mentioned the importance of the presence and quality of sidewalks. In case of absence of a sidewalk, characteristics of the streets and their shoulders were discussed. Streets with busy traffic or an uneven surface were perceived as less attractive to walk on. When a shoulder was present to walk on, uneven or muddy surfaces were disliked as well. When sidewalks were present, almost all participants mentioned issues related to the sidewalks' quality. They said they liked sidewalks that were well-maintained and even, and judged as hazardous and thus disliked cracked or uneven sidewalks, or sidewalks that had puddles, ice, snow, mud, or leaves. They also viewed sidewalks with steep cross-slopes as hazardous of becoming slippery during snowy and icy conditions. Adequate street lighting was mentioned as important for identifying fall hazards during walks after dark. Sidewalk width was also discussed. Participants preferred sidewalks wide enough for people to walk next to each other, to easily pass with a wheelchair and to maintain a safe distance from cars. To them, width means usable or walkable width. Walkable width narrows when a sidewalk has construction, parked cars, unkempt greenery and utility or light poles on it, all of which evoked negative responses. Separation of the sidewalk from motorized traffic by parked cars, bollards or vegetation was perceived as positive. Lastly, they said they disliked sidewalks that had high ramps to get on or off, slopes or stairs, because these elements increased the difficulty of walking. The presence of safe crossings was mentioned by some participants. Zebra crossings, supplemented with traffic lights in busy streets, were considered necessary to be able to cross streets safely. Participants reported to deviate from their shortest route in order to use a zebra crossing or traffic light to safely cross the street. Some participants expressed safety concerns related to the behaviors of other road users. Participants liked streets with slow traffic and disliked streets with speeding cars. This topic was mostly discussed near street crossings, especially when approaching cars were not visible (e.g. near sharp turns). Participants proposed solutions like speed bumps and chicanes to slow down traffic. On the other hand, participants also mentioned car drivers being

very courteous and giving priority to pedestrians at crossings. Not only speeding cars were disliked but careless cyclists on sidewalks were mentioned as dangerous as well.

3. Methods

3.1. Participants and Questionnaire

In order to investigate which critical issues old pedestrians found in the pedestrian paths they usually walk and how their age related declines in perceptual and physical abilities and their experiences as road user can affect the opinion on the critical issues of pedestrian paths, a survey was developed.

The investigation techniques based on surveys represent a very effective tool for the study of lot of issues of transport interest [36-41]. These techniques especially become indispensable when it is not possible to evaluate through experimental investigations the indicators associated with the subjective judgments of different road users.

A 22 items questionnaire was used to collect the participants' opinions. The questionnaire was divided into the following 5 sections:

- Section 1: participants reported their age, their gender and other basic socio-demographic characteristics information in the first section;
- Section 2: this section included questions regarding the experience as road users of participants. Participants were asked if they ever had the driving license, if they still drove, if they ever had accidents while driving and if they ever had accidents as pedestrians;
- Section 3: the third section contained questions about the age related declines of perceptual and physical abilities. Participants were asked if they had vision problems, hearing problems and mobility problems.
- Section 4: this section consisted of an open-ended question related to the critical issues of pedestrian paths. Participants could express freely their opinion related to the critical issues and the problems they found in the pedestrian paths they usually walked.
- Section 5: this section consisted of an open-ended question related to the solutions for critical issues of pedestrian paths. Participants could express freely their opinion related to the solutions they thought could improve the safety of pedestrian paths they usually walked.

The questionnaire underwent thorough piloting and revision, through 20 interviews face to face. This was done to ensure the suitability of the questions for the target people and to assess the acceptability of the wording, as well as the understanding of the questions.

Since the aim of this study was to explore the perception

of old pedestrians of the critical issues of pedestrian paths, this study focuses on the first four sections of the questionnaire.

The survey was conducted in 5 different locations in Catania, Italy. The locations were specifically chosen near to attraction poles for old pedestrians (e.g. centers for the elderly, squares, churches).

Participants were recruited in person, so as to select exclusively people over 70. Participants were briefed of the nature and time required to participate in the study prior to commencement. After their consent was obtained, the questionnaire started. It was decided to question directly the participants, instead of leaving them alone with the questionnaire, in order to provide visual aids and detailed explanations and clarifications. Each survey lasted approximately 20 minutes. Participants were assured of anonymity and confidentiality.

The total sample comprised 322 participants (164 men and 158 women). Participants who didn't complete the questionnaire or who gave uncertain answers were excluded. The respondents excluded were about 5% of the sample.

The final sample was composed by 306 participants (156 men and 150 women). The majority of respondents (50.33%) were aged between 70 and 75. 28.10% of respondents were aged between 75 and 80 and 21.57% of respondents were over 80.

3.2. Analytical Method

In order to analyze the survey data a cluster analysis was carried out. Cluster analysis is a multivariate data exploration method. The primary objective of this analysis is to identify groups or "clusters" based on the similarities between the data points or a "natural" grouping. This can be done with a single data point or a combination of data points of interest such a series of questionnaires. There are several ways to perform a cluster analysis, but the two primary methods are K-Means and Hierarchical.

K-Means clustering is the most commonly used unsupervised machine learning algorithm for partitioning a given data set into a set of k groups (i.e. k clusters), where k represents the number of groups pre-specified by the analyst. It classifies objects in multiple groups (i.e., clusters), such that objects within the same cluster are as similar as possible (i.e., high intra-class similarity), whereas objects from different clusters are as dissimilar as possible (i.e., low inter-class similarity). In K-Means clustering, each cluster is represented by its center (i.e., centroid) which corresponds to the mean of points assigned to the cluster.

The first step when using K-Means clustering is to indicate the number of clusters (k) that will be generated in the final solution. The algorithm starts by randomly selecting k objects from the data set to serve as the initial centers for the clusters. The selected objects are also known

as cluster means or centroids. Next, each of the remaining objects is assigned to its closest centroid, where closest is defined using the Euclidean distance between the object and the cluster mean.

This step is called “cluster assignment step”. After the assignment step, the algorithm computes the new mean value of each cluster. The term cluster “centroid update” is used to design this step. Now that the centers have been recalculated, every observation is checked again to see if it might be closer to a different cluster. All the objects are reassigned again using the updated cluster means. The cluster assignment and centroid update steps are iteratively repeated until the cluster assignments stop changing (i.e. until convergence is achieved). That is, the clusters formed in the current iteration are the same as those obtained in the previous iteration.

The basic idea behind K-Means clustering consists of defining clusters so that the total intra-cluster variation (known as total within-cluster variation) is minimized. There are several K-Means algorithms available. The standard algorithm is the Hartigan-Wong algorithm (1979), which defines the within-cluster variation as the sum of squared distances Euclidean distances between items and the corresponding centroid:

$$W(C_k) = \sum_{x_i \in C_k} (x_i - \mu_k)^2$$

where:

- $W(C_k)$ = total within-cluster variation
- x_i = a data point belonging to the cluster C_k
- μ_k = the mean value of the points assigned to the cluster C_k

Each observation (x_i) is assigned to a given cluster such that the sum of squares (SS) distance of the observation to their assigned cluster centers (μ_k) is minimized.

So, the final goal of K-Means is to minimize the total within-cluster sum of square.

$$\begin{aligned} \text{Tot. within - cluster} &= \sum_{k=1}^k W(C_k) \\ &= \sum_{k=1}^k \sum_{x_i \in C_k} (x_i - \mu_k)^2 \end{aligned}$$

This quantity also measures the compactness (i.e. goodness) of the clustering.

The second approach to a cluster analysis is the Hierarchical method. In contrast to K-Means, in the hierarchical method clusters are merged based on distance from each other. The method considers each data point as its own individual data point and then clusters data points based on the distance between each data point. At first, each data point is grouped with the data point closest to it as defined by one of the linkage methods for hierarchical clustering defined below:

- Single Linkage: the distance between the closest data points of the two clusters.
- Complete Linkage: the distance between the data points of the two clusters which are the farthest apart from each other.
- Average Linkage: comparing between all pairs and averages of all distances. Also called UPGMA – Unweighted Pair Group Mean Averaging.
- Centroid Method: finding the mean vector location for each of the clusters and taking the distance between the two centroids.
- Ward’s Method: Uses statistical analysis methods such as error sum of squares and R-squared to determine groupings of data points.

Then, each of these groups is merged with the groups closest to its group mean, and so on. This continues until all groups have been merged.

The optimal number of clusters with the Hierarchical method is determined by the minimum number of groups with the maximum amount of distance between group means. Frequently, this is illustrated with a dendrogram of the merging clusters.

Using a dendrogram, the ideal number of clusters is determined by the number of clusters intersected when drawing a vertical line through the largest horizontal distance between merging clusters.

3.3. Model development

Cluster analysis was used in this study in order to explore the safety perceptions of elderly pedestrians. Starting from the results of the survey, cluster analysis was developed to answer the following research questions:

1. Can we group together old pedestrians with a similar perception of critical issues of pedestrian paths?
2. How can we interpret the groups obtained? What do old pedestrians belonging to the same group have in common?
3. Which variables do mostly affect the determination of the groups?

The nominal variable considered is “critical issues of pedestrian paths”, with the sixteen possible items showed in Table 1. These items were deduced from the open-ended question related to the critical issues of pedestrian paths of Section 4 of the questionnaire.

The 8 variables considered are instead showed in Table 2. The variable *No driving license* indicates whether the respondents had not ever got the driver license, that means whether the respondents had not ever drove. The variable *No still driving* indicates whether the respondents were not still driving when they answered the questionnaire. The variable *Accidents driving* indicates whether the respondents had ever had an accident when they were driving. The variable *Accidents pedestrian* indicates whether the respondents were ever hit by a car (or another

vehicle) when they were walking. The variables *Vision problems*, *Hearing problems* and *Mobility problems* indicates whether the respondents have vision, hearing or mobility problems respectively. These variables are therefore representative of the respondents' age related declines in perceptual and physical abilities of respondents. Finally, the variable *Gender* of respondents was included in the analysis.

Table 1. Nominal variable: critical issues of pedestrian paths

Critical issues of pedestrian paths	
1	Sidewalks too narrow
2	Absence of sidewalks
3	Uneven sidewalks
4	Presence of obstacles on sidewalks
5	Absence of pedestrian crossing
6	Faded pedestrian crossing
7	Incorrect positioning of pedestrian crossing
8	Absence of ADA ramps on sidewalks
9	Vehicles parked on the sidewalks
10	Parked vehicles that obstruct pedestrian crossing
11	Inadequate drivers' behavior
12	Damaged road pavement
13	Roadway too narrow and absence of sidewalks
14	Absence or inadequacy of street lighting
15	Absence or inadequacy of signalized pedestrian crossings
16	Other

Table 2. Variables used for the cluster analysis

No driving license	No	66,67%	Yes	33,33%
No still driving	No	48,37%	Yes	51,63%
Accidents driving	No	39,87%	Yes	60,13%
Accidents pedestrian	No	24,18%	Yes	75,82%
Vision problems	No	52,94%	Yes	47,06%
Hearing problems	No	32,03%	Yes	67,97%
Mobility problems	No	24,18%	Yes	75,82%
Gender	Male	50,98%	Female	49,02%

4. Results and Discussion

4.1. K-Means Cluster Analysis

As shown in Table 3, critical issues of pedestrian paths were grouped in clusters by using SPSS software. To use K-Means clustering, the number of clusters is arbitrarily determined, either from existing knowledge of the data and the approximate number of groups you want to divide the data into. Of course, a good approach to K-Means is to try several numbers of clusters and see which number best

represents the data or produces any significant differences in analysis. Different models of clusters were therefore estimated, from one to seven, for selecting the suitable number of clusters. For further analysis, the critical issues of pedestrian paths were divided into five clusters. Table 3 shows the clusters membership.

Table 3. Clusters membership

Critical issues of pedestrian paths	Cluster	Distance
1	3	0.242
2	2	0.000
3	3	0.185
4	3	0.244
5	5	0.286
6	5	0.247
7	3	0.420
8	5	0.365
9	3	0.238
10	1	0.000
11	5	0.327
12	3	0.432
13	3	0.277
14	4	0.000
15	3	0.318
16	3	0.314

The first cluster is composed only by item 10, i.e. "parked vehicles that obstruct pedestrian crossing". This cluster can therefore be named *Irregular parking*. Cluster 2 is composed only by item 2, i.e. "absence of sidewalks". The second cluster can therefore be named *Absence of sidewalks*. The third cluster groups together 9 items, i.e. item 1 ("sidewalks too narrow"), item 3 ("uneven sidewalks"), item 4 ("presence of obstacles on sidewalks"), item 7 ("incorrect positioning of pedestrian crossing"), item 9 ("vehicles parked on the sidewalks"), item 12 ("damaged road pavement"), item 13 ("roadway too narrow and absence of sidewalks"), item 15 ("absence or inadequacy of signalized pedestrian crossings"), item 16 ("other"). Cluster 3 can therefore be named *Problems of sidewalks and of the correct use of pedestrian crossings*. Cluster 4 is composed only by item 14, i.e. "absence or inadequacy of street lighting". The fourth cluster can therefore be named *Absence or inadequacy of street lighting*. Finally, Cluster 5 groups together 4 items, i.e. item 5 ("absence of pedestrian crossing"), item 6 ("faded pedestrian crossing"), item 8 ("absence of ADA ramps on sidewalks") and item 11 ("inadequate drivers' behavior"). Cluster 5 can therefore be named *Problems of pedestrian crossings and of drivers' behavior*.

Table 4 shows the ANOVA analysis results and allows to understand which variables affect more the identification of the clusters. The variables mostly

contributing to the identification of the clusters are *Driving license* (Sig.=0.000), *Still driving* (Sig.=0.000), *Gender* (Sig.=0.000), *Vision problems* (Sig.=0.002) and *Accidents driving* (Sig=0.028). *Accidents pedestrian* (Sig=0.299), *Hearing problems* (Sig=0.117) and *Mobility problems* (Sig=0.115) are instead the variables less affecting the division into different clusters.

Table 4. ANOVA analysis results

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
No driving license	0.083	4	0.006	11	13.109	0.000
No still driving	0.137	4	0.010	11	13.987	0.000
Accidents driving	0.101	4	0.024	11	4.122	0.028
Accidents pedestrian	0.028	4	0.020	11	1.393	0.299
Vision problems	0.109	4	0.012	11	9.018	0.002
Hearing problems	0.039	4	0.016	11	2.363	0.117
Mobility problems	0.037	4	0.015	11	2.381	0.115
Gender	0.148	4	0.008	11	19.157	0.000

The judgment expressed by the elderly on the critical issues of pedestrian paths seems to be significantly linked to gender, to the experience as road users, and to vision problems that compromise the correct perception of the road environment. On the other hand, the least significant variable in conditioning the judgment on critical issues is that associated with road accidents that respondents had pedestrians. Hearing and mobility problems, even if conditions the perception of urban pedestrian paths, are less significant than sight problems. Basically, in identifying the critical issues of pedestrian paths, the elderly are mainly conditioned by the difficulty of correctly seeing the paths themselves and of perceiving the information deriving from the road environment as a whole.

Table 5 shows the profiles of the clusters obtained with the K-Means procedure.

Each group is represented by a center which originate a vector (row) whom components are the means of the values of the variables that defines the coordinates of the objects belonging to that group. The final cluster centers can range from 0 to 1. The closer the value is to 1, the closer is the condition "Yes" expressed by the variable (except for the variable *Gender* for which the closer the value is to 1 the more are women than men). These conditions are all representative of age related declines in perceptual and physical abilities (vision, hearing and mobility problems)

or of experiences as road user (no driving license, no still driving, accidents driving, accident pedestrian) which can affect the opinion on the critical issues of pedestrian paths.

The characteristics of the five clusters are given below.

- Cluster 1 (*Irregular parking*): All respondents of this group are men. Moreover, the majority of respondents belonging to this group had accidents while driving.
- Cluster 2 (*Absence of sidewalks*): This group is mainly composed by women who don't drive anymore, who never had the driving license and have vision and hearing problems.
- Cluster 3 (*Problems of sidewalks and of the correct use of pedestrian crossings*): Table 5 shows that no particular characteristics of respondents belonging to this group can be identified. This suggests that respondents who identify these critical issues of pedestrian paths don't have particular characteristics. This also suggests that critical issues associated to cluster 3 are commonly perceived by pedestrians regardless of age related declines in perceptual and physical abilities and regardless of their experiences as road users.
- Cluster 4 (*Absence or inadequacy of street lighting*): All respondents of this group had accidents while driving and are men.
- Cluster 5 (*Problems of pedestrian crossings and of drivers' behavior*): Table 5 shows that no particular characteristics of respondents belonging to this group can be identified. This suggests that respondents who identify these critical issues of pedestrian paths don't have particular characteristics. As with cluster 3, the critical issues associated to cluster 5 are commonly perceived by pedestrians regardless of age related declines in perceptual and physical abilities and regardless of their experiences as road users.

Table 5. Final cluster centers

	Cluster				
	1	2	3	4	5
No driving license	0.00	0.68	0.29	0.00	0.21
No still driving	0.45	0.91	0.52	0.00	0.30
Accidents driving	0.82	0.55	0.46	1.00	0.41
Accidents pedestrian	0.45	0.31	0.23	0.00	0.27
Vision problems	0.73	0.78	0.62	0.40	0.28
Hearing problems	0.27	0.52	0.25	0.00	0.18
Mobility problems	0.45	0.30	0.13	0.00	0.22
Gender	0.00	0.78	0.50	0.00	0.29

Table 6 shows the Euclidean distances between the final cluster centers. The higher is this distance, the higher is the difference between groups. It can be seen that the distance between cluster 3 and cluster 5 is the minimum (0.478). That is a confirmation of the fact that cluster 3 and cluster 5 are similar. For both these clusters, indeed, no particular characteristics of respondents were identified.

Table 7 summarizes the "profiles" of the elderly pedestrians identified in relation to the 5 clusters defined by means of the K-Means cluster analysis

Table 6. Distances between final cluster centers

		Cluster				
		1	2	3	4	5
1			1.209	0.793	0.906	0.791
2	1.209			0.725	1.644	1.109
3	0.793	0.725			1.034	0.478
4	0.906	1.644	1.034			0.858
5	0.791	1.109	0.478	0.858		

Table 7. Profiles of the elderly pedestrians obtained from the K-Means cluster analysis.

Cluster		Variables							
		Gender	No driving license	No still driving	Accidents driving	Accidents pedestrian	Vision problems	Hearing problems	Mobility problems
1	Irregular parking	♂			✓				
2	Absence of sidewalks	♀	✓	✓			✓	✓	
3	Problems of sidewalks and of the correct use of pedestrian crossings								
4	Absence or inadequacy of street lighting	♂			✓				
5	Problems of pedestrian crossings and of drivers' behavior								

The following considerations can be made:

- 1) the critical issues concerning the correct use of sidewalks and pedestrian crossings (cluster 3 and cluster 5) are not associated with a specific "profile" of elderly pedestrian. These critical issues, therefore, constitute a safety deficit highlighted in a systematic manner by almost all the sample of users interviewed;
- 2) also the problems related to aggressive drivers' behavior are highlighted almost indiscriminately by all the respondents;
- 3) the problem of irregular parking (cluster 1) and the problems related to the absence or the inadequacy of street lighting (cluster 4) are mainly indicated by men who had driving accidents during their experience as road users.
- 4) the "profile" constituted by women who have never driven and who have sight and hearing problems is associated with the problems related to the absence of sidewalks (cluster 2).

4.2. Hierarchical Cluster Analysis

Hierarchical clustering allows to confirm the number of clusters which was hypothesized with the K-Means clustering. The optimal number of clusters with the hierarchical method is determined by the minimum number of groups with the maximum amount of distance between group means. Frequently, this is illustrated with a dendrogram of the merging clusters. Using a dendrogram, the ideal number of clusters is determined by the number of clusters intersected when drawing a horizontal line through the largest vertical distance between merging clusters. Similar to K-Means, the optimal value of clusters must be chosen, but this method gives some perspective as to what the ideal value may be.

The hierarchical clustering allowed to illustrate the hierarchical organization of groups as shown in the dendrogram of Figure 1.

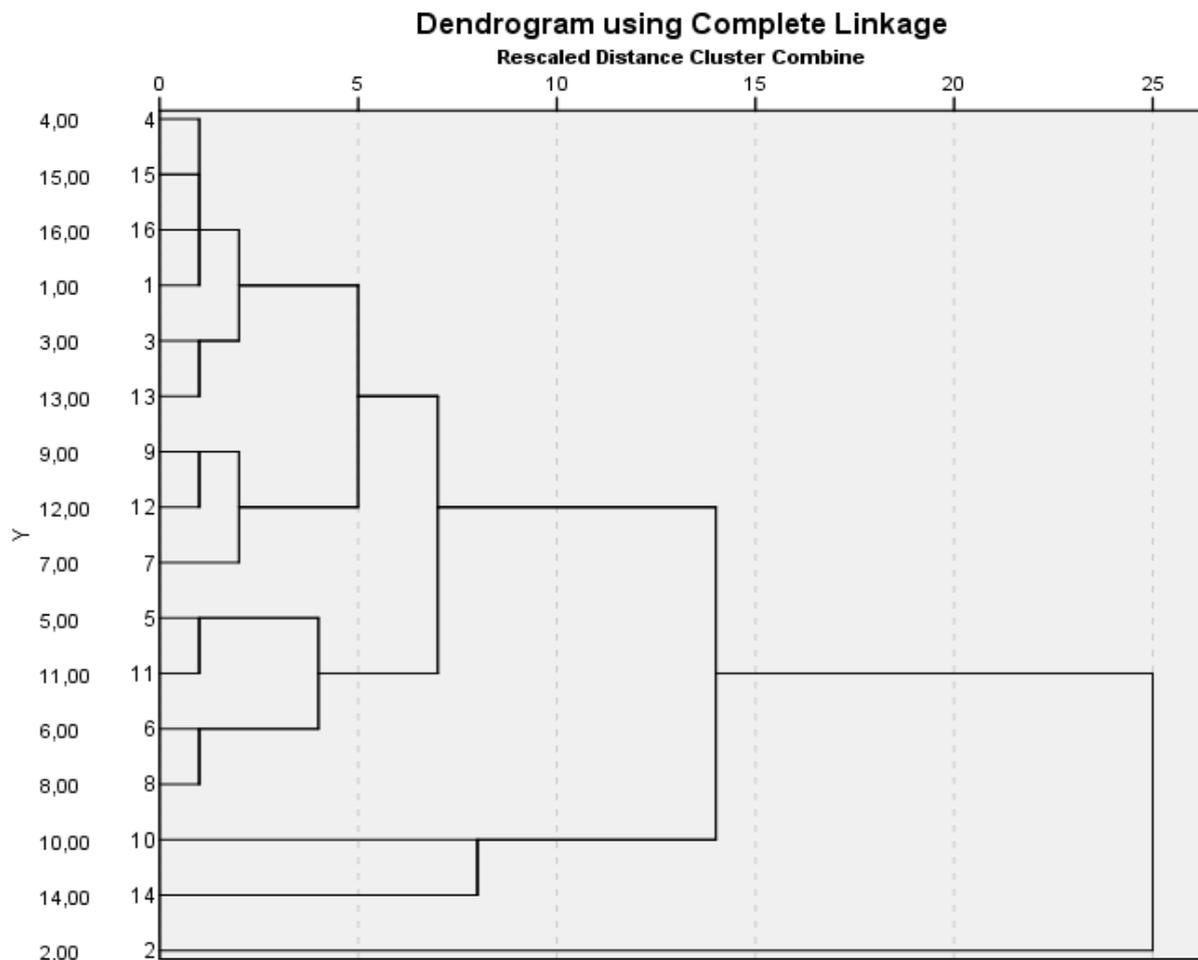


Figure 1. Hypothesis scheme

This visualization confirms the previous result, but offers also a hierarchical view of the clusters. By cutting the dendrogram at height 6, corresponding to the highest jump between levels of similarity, five clusters homogeneous as for their level of perceived safety are obtained. These clusters correspond to the five clusters resulting from the K-Means cluster analysis. The hypothesis made for K-Means cluster analysis was therefore fully confirmed by hierarchical cluster analysis.

5. Conclusions

It is widely recognized that human factors may contribute to accident involvement in traffic [42,43]. The literature on human factors and road user behavior is extensive (e.g. [44, 45]). The understanding of pedestrian behavior in urban contexts may assist to improve design and planning of road and traffic environment, and consequently to improve of pedestrian comfort and safety. It has also been shown that road and traffic factors alone may explain only a small part of pedestrian walking and crossing behavior in urban areas [46]. However, human factors related to pedestrians have received less attention in

the literature compared to other road users [47].

This study wants therefore to understand how human factors influence elderly pedestrian perception of critical issues of pedestrian paths. The aspects related to human factors considered were the gender, the factors associated with the experience as road users and the factors related to age related problems (mobility, vision and hearing problems). More specifically, the aim was to capture and analyze the key components that influence the elderly pedestrians' perception of pedestrian paths and to identify how these perceptions change for different pedestrian "profiles" based on human factors.

The results of this research show that the judgment expressed by the elderly on the critical issues of pedestrian paths they usually walk is significantly linked to gender, to their experience as road users, and to vision problem, which compromise the correct perception of the road environment. However, cluster analysis allowed to identify few "profiles" of elderly pedestrians with regard to their perception of critical issues of pedestrian paths. These findings should be considered in light of the limitations of the present research. Extending the survey to a larger and more representative sample may reveal additional critical issues and additional "profiles" of elderly pedestrians.

Moreover, the limits associated to the specific sites considered for the survey have to be considered.

Despite the aforementioned limits, the results have however showed important confirmations regarding the problems of urban pedestrian paths which are a priority for elderly users. The "profiles" identified, although few in number, are indeed perfectly consistent with the different elderly users' characteristics, capabilities and needs that should be considered and prioritized when designing pedestrian safety measures.

Age is connected to a variety of characteristics and skills that influence the risk of pedestrian traffic injury. These age-related characteristics can also affect the way in which people of different ages interact with pedestrian safety measures and require therefore particular attention when planning road safety measures.

Several factors work together to increase the risk of older pedestrians [12, 48]:

- Deterioration in visual acuity may have a negative impact on their ability to cross the road safely. In general, older pedestrians look less at traffic and accept significantly smaller gaps in traffic when crossing the road than younger pedestrians.
- Reduced mobility can render older pedestrians unable to react quickly in imminent danger to avoid a crash.
- Health conditions or frailty can result in greater injury severity when a crash occurs.
- The speed of elderly pedestrians does not itself increase the accident risk: the risk comes from the speed of the traffic and, in particular, from automated signals that do not allow sufficient time for slower pedestrians to cross safely.

The following measures can be implemented to improve the safety of older pedestrians, also contributing to the improvement of environmental quality through the reduction of noise and atmospheric pollutants [48, 49, 50, 51]:

- Increase the time allocated to pedestrians at midblock signalized crosswalks.
- Install midblock high-visibility crosswalks.
- Repair broken sidewalks and pedestrian ramps.
- Replace missing and/or upgrade existing signs.
- Install pedestrian refuge islands or, preferably, raised medians.
- Install traffic-calming measures at streets with high pedestrian flows.
- Reduce interactions between pedestrians and other road user types through the physical separation of flows in urban areas using for example raised planter boxes and outdoor seating and the use of wider sidewalks.
- Improve the conspicuity of pedestrians for drivers.
- Improve the perception of elderly pedestrians about other road users.

At road intersections, roadway design and signalization

play a critical role to pedestrian safety. Some interventions that could be implemented are the following [50, 52]:

- Adjusting the traffic signals to allow for the slower walking speed of elderly pedestrians in intersection areas.
- Use of exclusive pedestrian signal phases.
- Use of protected phases during signalization.
- Pedestrian islands or sidewalk extensions in urban areas.

Moreover, roundabouts have a positive impact to safety especially when constructing large splitter islands, banning parking near roundabouts, using adequate street lighting, speed reduction installations, reduced width of circular carriageway, as well as increased deflection and improved signing [36, 39, 41, 50]. The roundabouts also contribute to improving the liveability and pleasantness of the pedestrian paths, giving rise to environmental improvements such as the reduction of atmospheric and acoustic pollution [53].

Out-of-vehicle ITS applications have the potential to enhance speed limit compliance. These applications include dynamic messaging, in the form of active speed warning signs and variable message signs [48, 50].

Regarding conspicuity, measures should target [48, 50]:

- Lighting at intersections and pedestrian crossings.
- Installation of conspicuous 'give way to pedestrian' signals.
- Reflective pavement markings.

Regarding behavioural factors, for example risk taking behaviours such as the inability to scan and react properly to urban areas and so on, successful countermeasures may include [48, 50]:

- Educational campaigns to promote the use of specialized clothing.
- Educational campaigns to increase the awareness of age-related cognitive and sensory declines.
- Raise public awareness about the safety needs of elderly pedestrians.
- Inform and train pedestrians about the proper behavior to adopt on the road or related to novel traffic rules, situations and road layouts in urban and rural areas
- Reduce legal speed limits.
- Strengthen enforcement of laws on speed limits, and drink-driving.

In a future study, the authors intend to use section 5 of the questionnaire (related to the solutions for critical issues of pedestrian paths proposed by the respondents) to verify which of the actions and strategies indicated above were actually considered a priority by the elderly interviewed.

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