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Cyberspace vs. Physical Space: A Model for Upgrading the Social Performance of Urban Fabric (The Case of Sana'a City)

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Abstract: **Purpose** - Sana'a is a unique example of an Arab Islamic city that was bounded within its walls until the late 1960s. Its urban fabric offered a great deal of social cohesion and connectivity and had high social performance. In the last 60 years, the city exploded in size and population. This boom led to the degradation of the social performance of the urban fabric among many other urban transformations. Sana'a also witnessed gradual advancements in its communication systems. These developments eventually led to the installation of some ICT applications, such as the Internet. Hence, cyberspace became a reality in the lives of many of the city's residents today. The aim of this paper is to answer the following question: What is the potential role of cyberspace in upgrading the social performance of the urban fabric of Sana'a?

Design/methodology/approach - This research hypothesizes that cyberspace has a higher, more detailed potential in social upgrading. This research will present a model based on "upgrading modes" of cyberspace for the urban fabric. First, the general upgrading modes will be presented. Then, the upgrading modes of the social performance of the urban fabric will be derived.

Findings – It is concluded that Sana'a is in a state of socio-spatial fragmentation, segregation, and fragility and has a dysfunctional social performance. Moreover, cyberspace has a significant presence in the city and has attracted notable official and public awareness. The upgrading modes and social upgrading modes were applied on a selected urban fabric in Sana'a. Findings indicate that the social upgrading models of cyberspace can upgrade the city's urban fabric by up to 79%.

Originality/value - This research presents an empirical model that acknowledges the integrated relationships between cyberspace and physical space. The research also explores the enabling potential of cyberspace to solve certain urban problems (in this case, its insufficient social performance).

Keywords: cyberspace (CS), physical space (PS), public urban space (PUS), social performance, urban fabric.

1. Introduction

Sana'a was bounded within its walls until the late 1960s. It is a unique example of an Arab Islamic city (Hzem, 2006). Its high-quality urban form responded to the natural, cultural, social, religious, economic, technical, and political needs of its inhabitants (Al-Gazali, 2008).

In the social realm, the city's urban gradient fostered and nurtured social interaction effectively and offered a great deal of social cohesion and connectivity. Thus, Sana'a had high social performance (Hzem, 2006).

In the last 50 years, Sana'a started to witness significant political, economic, and social changes, similar to most Arab cities in that period. These changes were driven by national, regional, and international events and changes. They were the

drivers of significant administrative, physical, and socio-spatial transformations, which have started escalating in the city since then (AlKokabany, 2008).

Gradual degradation of the socio-spatial qualities of the urban fabric occurred, leading to the fragmentation and disruption of the local identity, continuity, and cohesion in the urban fabric, and in an increase of socio-spatial segregation. In a socio-spatial diagnosis, Al-Abed (2011 b) describes Sana'a today as "fragmented and socio-spatially segregated." It has also been classified within the entire country to be among the cities experiencing what the World Bank has called "social fragility" (Marc et al., 2013). The city's urban fabric social performance can then be said to be degraded.

With the new political and social demands and orientations, and in response to international and regional changes, the city witnessed gradual advancements in its communication systems, among other advancements in communication systems in the country as a whole. These advancements eventually lead to the installation of some information and communication technology (ICT) applications, such as the Internet in 1996 and mobile communication in 2001 (Ghanim, 2008).

With the installation of the Internet, the city tuned in to cyberspace (CS). Although it was modestly introduced at the beginning, the usage of the Internet has been growing rapidly in the entire country and has reached a penetration rate of approximately 15% in 2012 (World Bank, 2013). Sana'a has had the biggest share of this usage in Yemen. More people are entering CS through different ICT means and engaging in it for different reasons. CS has become a reality in the lives of many of the city's residents today (ESCWA, 2011).

The theoretical approaches toward ICT-based urban changes are classified into two main theories: technological determinism theory and non-determinism theories.

On the one hand, technological determinism assumes that technology directly causes urban changes that are autonomous from other social, political and economic urban forces. CS in this theory is assumed to have a single relationship with public urban space (PUS): the substitution relationship. Technological determinists speculated that ICTs will lead to the death of distance, the end of geography, and the dematerialization of cities (Graham, 1998).

On the other hand, non-determinism theories, being more recent, criticize the simplicity and one-dimensionality of technological determinism and its failure to capture urban dynamics. Non-determinists believe that the relationship between technology and the urban fabric is much more complex and that technology and other urban forces interact to create urban change. With focus on the present rather than the future, they state that many speculations of the technological determinism theorists have not come about. However, ICT shifts in urban dynamics have proven to be more dramatic than any of these speculations, albeit with a different, more complex form (Rahoumah, 2005).

With the non-deterministic theories in mind and because Sana'a is in a state of social fragmentation, segregation, and dysfunctional social performance, this research aims to answer the following question: Can CS have a potential role in upgrading the social performance of the urban fabric of Sana'a?

In addition to the introduction, methodology, and conclusion, and to address the research question, the literature review will focus on the following:

- CS vs. urban fabric: the theoretical approaches
- CS from a social perspective

2. CS vs. Urban Fabric: The Theoretical Approaches

Various schools were considered with regard to the effects of ICTs on physical space (PS) (Muhammad, 2007). The theoretical approaches toward ICT-based urban changes can be classified into two types: technological determinism approach and non-determinism approaches (Fig. 1).

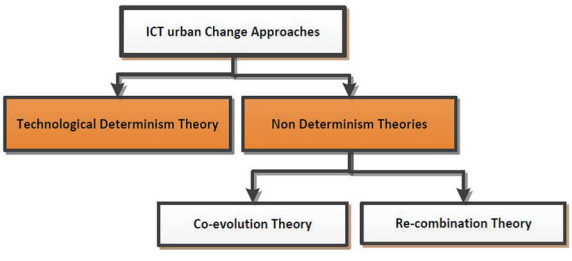

Figure 1. Prominent ICT-based urban change theoretical approaches.

2.1 Technological Determinism Theory

Technological determinism theory is one of the prominent theories that dominated the socio-technological urban research arena especially during the early 1980s and mid-1990s. In this theory, modern telecommunications are seen as a "shock," "wave," or "revolution" impacting or about to impact upon cities, directly causing urban changes and having some form of autonomy from social and political changes. Cities are seen to be placed in a new "age" in which telecommunications increasingly have a prime role in reshaping their development. To technological determinists, the transformation toward an "information society," "postindustrial society," "information age," "communications revolution," or "Third Wave" is universal and inevitable and is imposed upon the global urban societies and their urban fabrics (Graham, 1997).

They also consider CS and PS as two separate realms that oppose each other and have a one-way (CS to PS) impact and relationship between them. Such technologically determinist predictions also resonate surprisingly strongly with some of the more critical recent perspectives of the relationships among space, place, and technological change (Crang et al., 2007

2.1.1 Substitution: Determinism CS vs. PUS Relationship

Stemming from the technological determinism theory, most of the earlier futuristic assumptions were based on the substitution relationship between CS and PUS as the only possible form of relationships. The substitution-based assumption of urban change was not the brainchild of ICTs. In fact, arguments of substitutionists have a long lineage dating back to the late nineteenth century.

Back then, seemingly fantastical technologies of the telegraph, wireless, and telephone would annihilate space constraints through minimizing time constraints. From the writings of Edward Bellamy in 1897, Marshall McLuhan and Melvin Webber in 1968, and Naisbitt and Aburdene in the 1980s and 1990s, futurists were riding a wave of excited speculations of the trade-offs between communication means and the PUS (Graham, 1998).

2.1.2 Urban Implications of Substitution

The importance of the urban implications of substitution is presented below:

2.1.2.1 Death of Distance and End of Geography

A broad consensus of deterministic assumptions exists, which branches out from substitution. The most extreme position is probably taken by the proponents of the "death of distance" thesis by Schwanen (Kwan, 2008), proposed by Carnicos, and the "disappearance of distance" (Al-Mad'hagi, 2009) and "the end of geography" theories (Muhammad, 2007), which are also headed in the same direction. However, what do these terms stand for and what are they based upon?

Virillio, a French urban theorist and philosopher, explains this notion by arguing that ICTs now mean that the distinction between departure and arrival is increasingly lost (Marvin, 1997). As a result, geography and spatial dynamics either cease to matter at all or are likely to be of much reduced significance. According to Couclelis, economic and other activities are no longer linked to geographic locations (Muhammad, 2007). Thus, many analysts felt that location would become irrelevant (Kotkin & Devol, 2001) or that people would end up, as Kotkin called it, "living in a placeless society" (Moss & Townsend, 2000)

2.1.2.2 Dematerialization of Cities

The death of distance, according to substitutionists, results in the expiration of the importance of physical closeness. With the lessening importance of the geographical location of dwellings, many residents will move to farther locations from the classical dense urban centers (Al-Mad'hagi, 2009).

In Alvin Toffler's influential "Third Wave" scenario, for example, people are liberated from having to live in the city and can escape to the rural idyll to live in an "electronic cottage" (Graham, 1997).

New rural societies will emerge as people exercise their new freedom to locate in small, attractive settlements that are better suited to their needs. From here, Anthony Pascal, among others, considered that the era of the computer and the communication satellite is inhospitable to the high-density city (Graham, 1998).

Moreover, shifts in the importance of different types of infrastructure networks will occur. The early infrastructure networks of railways, highways, factories, cities, and water supply accounted for a large part of material-intensive economic activity in the nineteenth and twentieth centuries. New infrastructure will be based and built around natural gas, information systems, telecommunications, and

satellites. The physical requirements related to this growth are certain to be less material intensive than the industrial phase of development (Marvin, 1997).

From here, telecommunications will lead to the dispersal of urban space and will unglue the urban life. It will also dissolve the glue that holds cities together.

According to Pascal, the face-to-face contact, which is the main reason for the existence of the traditional city, is no longer crucial. Thus, Toffler and Virillio, among many others, strongly suggest that the relationship between CS and PUS will lead to the dematerialization of the city (Marvin, 1997).

Gillespie and McLuhan reached the extreme of assuming the dissolution of the urban fabric or even the effective dissolution of the city itself (Yanarella et al., 2000). Even national borders will become irrelevant, redundant, and obsolete (Muhammad, 2007).

2.2 Non-Determinism Theories: The Basic Principles

Non-determinists, such as Drewe, say that we are, however, sure that no simple, direct links exist between ICT and the spatial patterns of cities and regions (Drewe, 2005). In fact, considerable evidence suggests that the relationship is much more complex, starting from CS–PUS interactions and reaching the actual "development of spaces" (Crang et al., 2007).

Graham (1998) argues that ICTs and cities stand in a state of recursive interaction, shaping each other in complex and diverse ways. Researchers should look for rich empirical details at the complex ways in which ICT technologies are being used in real ways in real places to embrace the complex hybrid nature of urban spaces.

Both virtual spaces in CS and PUS are necessarily produced together in complex articulation between the two realms rather than assuming some simple substitutional relationship. They stand in a state of recursive interaction, shaping each other in complex ways. Relational rather than absolute theories of time and space are rapidly gaining influence in geography and urban studies.

Recombination theory argues that, outside such relational complexity, the meaning and effects of new information technologies can never be fully understood or simply generalized. Its argument is that a fully relational view of the links between technology, time, space, and social life is necessary. Place becomes an embedded and heterogeneous range of time–space processes. Thus, absolute spaces and times are meaningless in this theory.

2.2.1 Non-Deterministic Perspetives: The Urban Implications

Many ICT-based urban phrases were mentioned by scholars to describe the alternative prospects, which are based on the non-deterministic logic, instead of virtual spaces substituting for PUS. Graham and Marvin presented the "feed off and fuel" phrase, which presented the complex relationship between the two spaces. Instead of the "death of distance" and "dematerialization of cities and urban spaces, " Malecki and Gorman said that it may be the death of distance but not the end of geography. Wilson and colleagues presented the phrase "the rise of the new place." To address the new situation as a whole, according to Mitchell, an old script was replayed with new actors with silicon as the new steel and the Internet as the new railroad (Muhammad, 2007)

3. Cyberspace from a Social Perspective

Does technology really affect the society or the other way around? This debate has been taking place among scholars for decades.

Rahoumah (2005) argues that in this age of information, post-industrialization, and post-modernism, the machine (computer) and the computerized mind with all its stunning developments are the center of the current social changes. The case of the machine/human society and the social change from its natural human environment to its human mechanical environment may be the most important cases facing the human society today.

Rahoumah (2005) considers that technology has always been linked to development and also to social change, which has been "an active tool in other forms of change in human civilizations."

Moreover, according to Schwanen and Kwan (2008), for several decades now, commentators in the field of science, technology, and society studies have argued that an essential task is to take into account the dynamic interactions between technological changes and social processes rather than discuss technology exclusively in terms of tools or instruments employed to achieve a certain goal.

Preece and Dian (2003) also say that social scientists seek to answer questions about how the

Internet (the technology) is changing our lives.

Contrary to the technological determinism theory, social determinism assumes that the social forces take the lead in advancements in technology and monitor them, culture being one of its primary elements. Scholars who adopted this theory, such as Leslie White and Herbert K. Marcuse, considered that technology is inseparable from science, politics, economics, society, and culture in general (Rahoumah, 2005).

In comparing the two major theories mentioned above, Graham (1997) sees that such approaches are unhelpful, because they suggest that technological development is somehow separated from society, rather than being designed, applied, and shaped within specific political, social, economic, and cultural contexts. In fact, the effects of telecommunications are much "messier" than this simple view for two reasons. First, the design and production of telecommunications are clearly socially, economically, and culturally biased. Second, this bias does not shape all technological effects in all places. Once technologies are available, political and social struggle and actions can redirect their application and change their actual effects in each case, just as political and social influences can redirect the shaping of urban politics and the built environments of cities, which means that the effects of ICTs in cities can depend heavily on how they are socially and politically constructed.

Society and technology affect each other in different degrees and ways. Rahoumah (2005) considers the two factors, namely, technology and society, as one compound factor. Schwanen and Kwan (2008) took the same approach, in agreement with Latour, Callon, and Law, saying that the technological and social should be seen as both "cause and effect" of each other. Finally, Graham (1997) sees that, for a more sophisticated perspective, researchers need to accept that society and technology shape each other in complex ways. Theoretical models that conceptualize the "social" and "technological" to be caught up in complex and recursive interactions, rather than in separate realms, are required.

4. Methodology

The methodology was developed to achieve the main objective of this research, which is to answer the following research question: What is the potential role of CS in upgrading the social performance of the urban fabric of Sana'a?

This research assumes that CS has a higher, more detailed potential in social upgrading. This potential can be derived from the study of the types of integrated relationships between the two dimensions, CS and PUS. This research will present a model based on the "upgrading modes" of CS for the urban fabric. First, the general upgrading modes will be presented. Then, the upgrading modes of the social performance of the urban fabric will be derived. The term "urban fabric" was used instead of physical urban space because of the integrated relationship between the different physical urban spaces and the activity that takes place within them.

Two different steps were used to achieve the study objective: building the research model and applying the analytical model on a selected urban fabric in Sana'a.

4.1 Research model

Six relationships exist between CS and PUS [Fig. (2)]: neutrality, substitution, synergy, modification, enhancement, and generation. These relationships, together with the relationships of PUS and CS, intertwine to create the character of this new digital era. The integrated nature of these relationships creates the potential for great changes in the urban fabric in the present and future (Yu & Shaw, 2008).

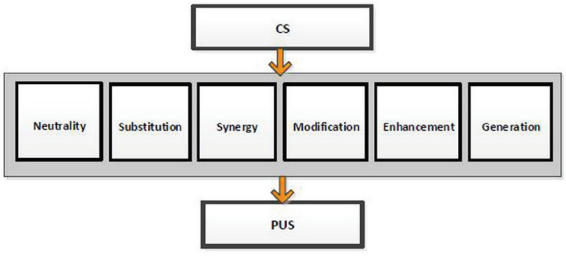

Figure 2. Prominent ICT-based urban change theoretical ap-Fig. (2) CS–PUS relationships. Source: Yu, Hongbo. Shaw, Shih-Lung. 2008, pp. 428.

● The relationships (neutrality, generation, and substitution) can be considered quantitative relationships in the following sense: Neutrality is the case of 0% virtual spaces and 100% physical spaces in which space is wholly physical. Absolute substitution is the case of 100% virtual spaces and 0% physical spaces in which space is wholly transformed to virtual. Between 0 and 100%, more

virtual space is quantitatively generated, leading to partial substitution of physical space. The space occurring here is the hybrid space (physical + virtual).

The wide range between 0% and 100% possibilities available can be seen for this combination in which recombinant design comes in action. In this sense, none of these relationships refer to the qualitative performance of the space, be it totally physical, totally virtual, or hybrid, which is actually the range that happens in real life and the potential that should not be overlooked. The quantitative relationships are clarified in Fig. (3).

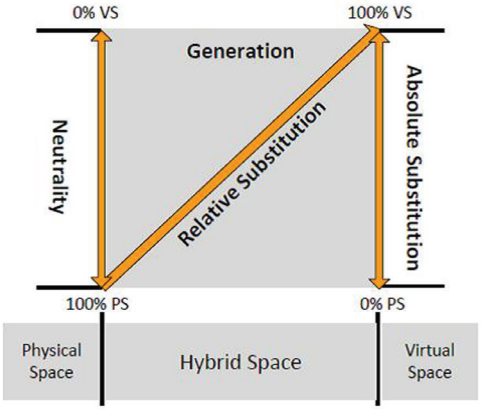

Figure 3. Quantitative relationships between CS and PUS.

Quantitative relationships have upgrading potential considering their better utilization of physical space. With the 0–100% substitution of spatial activity in the physical space, the physical space needed to accommodate it creates a potential for other needed spatial activities in the physical space.

● The relationships (synergy, neutrality, modification, and enhancement) can be considered qualitative relationships. In a qualitative sense, these relationships can be interpreted as follows:

♦ Synergy is the quality of dependence on spatial activities, patterns of distribution, and spatial characteristics of the physical space.

♦ Neutrality is the quality of not being related to the physical space. Neutrality, in a qualitative sense, can be considered to have a negative effect on the urban fabric.

♦ Modification is the quality of alteration, negative or positive, that CS has on PUS activities, systems, and spaces. They are the qualitative characteristics that carry the major difference between the two dimensions and make the other relationships possible.

♦ Enhancement can be considered a division of modification and also the quality of alteration. It is the quality of positive alteration if the performance of the 100% physical space can be graded X. After the quantitative modification and partial substitution in the range from 1% to 99% of it by CS and with synergy and neutrality qualitative relationships, the performance will still be X. With the modification qualitative relationship, it will be one of the three options: X, X+Y, or X-Y. In the enhancement qualitative relationship, it will be X+Y. That is, an increase in the performance of this urban fabric is found. The qualitative relationships are clarified in Fig. (4). Qualitative relationships have the upgrading potential through the enhancement relationship in hybrid space. The virtual spaces that exist in combination with PS enhance its spatial activity.

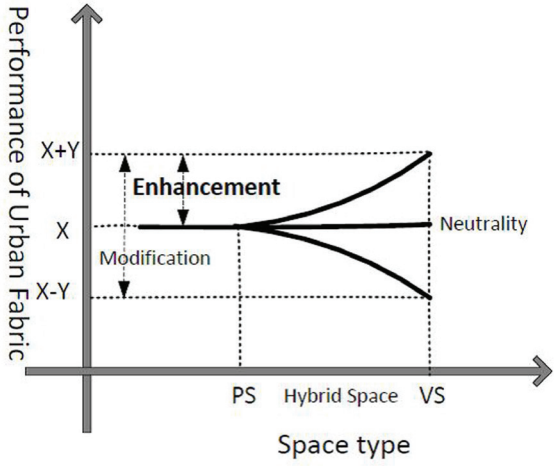

Figure 4. Qualitative relationships between CS and PUS.

The qualitative and quantitative potential upgrading relationships were mentioned separately above. However, intersections between them exist. One relationship can lead to the other from each group. Therefore, the potential of CS in upgrading the urban fabric is divided by the researchers into three main types. These types were called "upgrading modes" and are described as follows:

● EMA: Enhancement by mirroring an actual physical space for the sake of advertising its spatial activity

This enhancement takes place by creating a virtual space or part of a virtual space (VS1) in CS, which mirrors the original PS (PS1) and becomes its representative in CS. Here, the original spatial

activity (SA1) takes place entirely in PS and is not at all substituted by the virtual space. Enhancement is applied for the sake of widening the knowledge of its existence and enhancing its significance. This enhancement leads to another relationship, which generates movement (GM) toward and within PS1 due to this advertisement. EMA is illustrated in Fig. (5).

● **EMB: Enhancement by mirroring an actual physical space for the sake of carrying out or overtaking some of its original spatial activity**

In this mode, a virtual space or part of a virtual space (VS1) is also created in CS, which mirrors the original PS1. VS1 carries out or overtakes some of the original spatial activity of the PS1 (SA1). This type of enhancement can lead to relative or absolute substitution of (SA1) and therefore creates a potential of relative substitution (S1) or absolute substitution (S2) of PS1. Substitution of PS1 based on EMB is a potential for generating (GS) a new physical space (PS2) with its new physical spatial activity (SA2). The EMB upgrading mode is presented in Fig. (6).

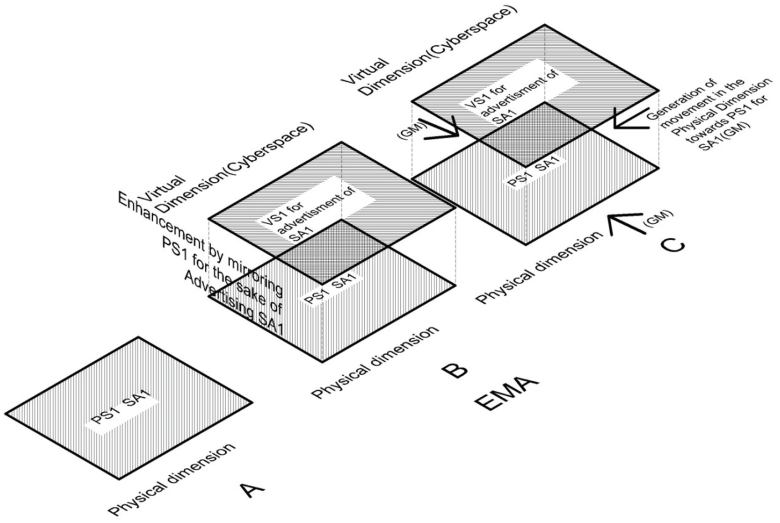

Figure 5. EMA upgrading mode

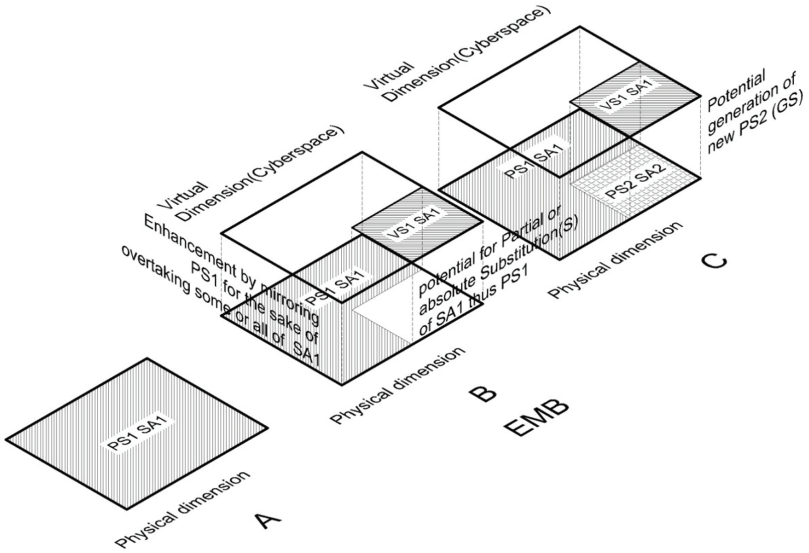

Figure 6. EMB upgrading mode.

● ES: Enhancement by a suggestive virtual space

In this mode, one or more virtual spaces (VS2, VS3, etc.) are created in CS and connected to the original PS1, but have different spatial activity/ activities (SA2, SA3, etc.). This type enhances the performance of PS1 by actually adding potentially more spatial activities to it, which can compensate for shortages in spatial activities on the physical dimension. This type of enhancement generates movement on the physical and virtual dimensions toward and within the physical space (GM). The illustration in Fig. (7) shows the ES upgrading mode.

The upgrading modes can exist solely or in combination with each other, which are further clarified in Table (1).

4.1.1 Social Upgrading Modes

The previously mentioned upgrading modes are general for different physical spaces in the urban fabric. They can be specialized to address the social dimension, that is, upgrade the social performance of a specific urban fabric. They can be summed as follows:

● EMA-Social

This upgrading mode achieves enhancement of a given PS1, which contains social spatial activities (SA1) by mirroring it in CS, thus leading to the expansion of the awareness and knowledge of PS1 and its social activity and generating more movement (GM) toward it in PS.

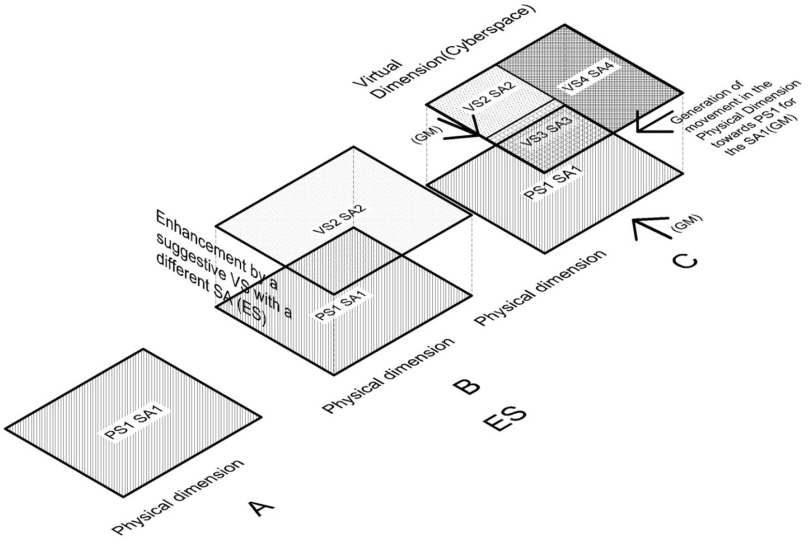

Figure 7. ES upgrading mode.

Table 1. CS upgrading modes of the urban fabric

No	Upgr ading Mode	CS vs. PS Relationship	On the Virtual dimension		On the physical Dimension	
			Action taken	performed task	Quantitative upgrading effects	Qualitative upgrading effects
1	EMA	Enhancement by a mirroring VS1	creating a VS1 that mirrors an actual PS1	broadening the knowledge of the spatial activity (SA1) of PS1 (Advertisement)	Generation of Movement to PS (GM)	Enhancement of significance of PS1
2	EMB	Enhancement by a mirroring VS1	creating a VS1 that mirrors an actual PS1	Carrying out some or all of SA1 in VS1	Decrease in needed PS to perform SA1, Partial Substitution (S1) or absolute Substitution (S2)	better utilization of PS in general-generation of other needed PS2 with new SA2 (GS)
3	ES	Enhancement by a suggestive VS2	creating a VS that is suggestive of a different SA linked to the original PS1 (VS2, VS3, etc.)	adds more SAs to the original SA1 (SA2, SA3, etc.)	Generation of Movement to PS1 (GM)	Enhancement of significance of PS1 - better utilization of PS in general

- **EMB-Social**

EMB is achieved through the general upgrading mode, EMB. The enhancement of a given PS1 by EMB, which leads to the potential partial substitution (S1) or absolute substitution (S2) of PS1, offers the potential for generation of needed social space (GS) in PS.

- **ES-Social**

In this social upgrading mode, a suggestive social space or location in a social space (VS) can be generated in CS and linked to the original PS, which leads to social interaction in CS and consequently leads to the generation of social interaction in PS, that is, the generation of movement within the physical dimension.

The three social upgrading modes and their effects on the basic elements of social performance, connectivity, and inclusion are clarified in Table (2).

4.2 Applying the Analytical Model

The research model will be applied on a selected urban fabric in Sana'a based on the following reasons:

- With an annual growth rate of more than 7% over the last 50 years, Sana'a has exploded in all directions from approximately 3.7 square kilometers in 1962 with 50,000–55,000 inhabitants to an administrative area of approximately 1,050 sq km with an estimated population of 2,824,000 persons in 2014 (Al-Abed, 2003) (OICC, 2004).

Sana'a is considered to be in a state of socio-spatial fragmentation, which is shared with the rest of the cities in the region. Sana'a is divided into different social fragments, each presenting a socio-economic character. Another research (Al-Abed, 2011a) considers Sana'a to be a city experiencing visible socio-spatial segregation. Social segregation in a city is associated with "the spatial separation of the different social groups in a geographical area according to ethnic, religious, or income differences, among others." The social performance of an urban fabric is related to the connectivity and cohesion it offers among its residents within natural and logical inclusion. Therefore, the general fragmentation and social segregation of Sana'a mean that it is socially disconnected and lacks cohesion. Thus, this research considers the city's urban fabric to be of low social performance.

- This low social performance has recently attracted international attention. In a report conducted by the World Bank in 2013, Yemen was considered among the countries experiencing social fragility. Fragility is related to "periods when states or institutions lack the capacity, accountability, or legitimacy to mediate relations between citizen groups and between citi-

Table 2. CS social upgrading modes of the urban fabric

No.	Social upgrading mode	CS vs. PS Relationship	On the Virtual dimension		Upgrading effects of Social Performance			
			Virtual Action	performed task	quantitative benefit (more)	qualitative benefit (better)	Connectivity	Inclusion
1	**EMA-social**	Enhancement by mirroring a social PS1	creating a social VS1, or a location in a social VS1 that mirrors an actual social PS1	broadening the knowledge of the social spatial activity (SA1) of PS1 (Advertisement)	Potential Generation of Movement to and within the Social PS1 (GM)	Enhancement of significance of the Social PS1	potential increase of connectivity in PS1	inclusion in PS and CS (Hybrid space)
2	**EMB-Social**	Enhancement by mirroring PS1	creating a VS1 that mirrors PS1	VS1 Carries out some or all of the SA1 virtually in CS	Decrease in needed PS to perform SA1, (Partial Substitution (S1) or absolute Substitution (S2)), generation of social PS2	Better utilization of PS1	Potential increase of connectivity in the VS1 and PS1	inclusion in PS and CS (Hybrid space)
3	**ES-Social**	Enhancement by a suggestive social VS2	Creating(or connecting to) a social VS2	VS2 performs social spatial activities virtually	Generation of Movement to PS1 due to virtual social activities (GM)	Compensating for social shortages in PS+ Enhancement of social significance of PS	Potential for increasing connectivity in PS and VS	More inclusion in CS and PS

zens and the state, making them vulnerable to violence." This situation hinders development processes and threatens the stability of the nation as well, which ranges in a continuum from the extreme form of state failure to experiencing various degrees and types of fragility (Marc et al, 2013).

● Sana'a has the highest share of communication services in the country, and the Internet is not an exception. According to the marketing section of the Internet and Data Transmission General Department of PTC, the number of ADSL subscribers in Sana's city reached 74,121 subscribers by the end of 2013. Thus, the number of users is estimated at approximately 370,605 persons. According to professionals in the PTC, this number is estimated to have increased during the last few months (Saeed, 2014)[1].

The previously mentioned determinants of Internet statistics in Yemen are applicable to Sana'a. The geographical distribution of the fixed broadband Internet service is divided into exchanges, and the exchanges are divided into cabinets. On the basis of the maps provided by the GIS Department in PTC, 15 main exchanges exist today in Sana'a (Saeed, 2014)[2]. These exchanges facilitate the fixed Internet services (Dialup and ADSL) in Sana'a. The rest of the Internet services are provided through mobile phone networks and satellites. Figures (8) and (9) show the geographical distribution and service areas of these exchanges and their geographical relationship to the administrative areas, the directorates.

The research model will be applied in five consecutive stages: selection, preparation, observation, assessment, and analysis.

Figure 8. Yemen locational map.

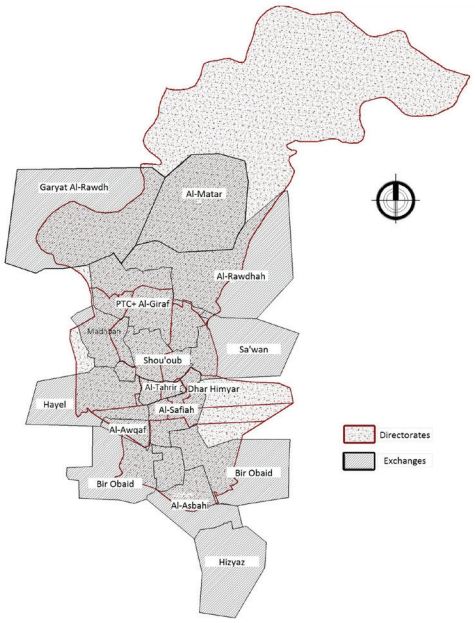

Figure 9. Geographical distribution and service areas of the Exchanges and their geographical relationship in Sana'a.

4.2.1 Selection Stage

The virtual dimension scope selected is the ADSL service provided by 'YemenNet'. This selection was determined after consultation with PTC professionals in the Marketing Section and the GIS Department in addition to communication engineers.

4.2.1.1 Virtual Dimension Scope

The selection of the Internet service types was based on the following:

● To link the virtual and physical dimensions in the city, the services sought were those that can be linked to a specific physical location. Thus, the mobile and satellite phone statistics and subscribers were eliminated, and the fixed-type services were selected (Al-Wadee & Assem, 2014)[3].

● The highest fixed-type service subscribers are the dial-up and ADSL, which are also the statistics that are adopted in the national and international statistics of the Internet usage. PTC personnel mentioned that, after 2010, the dial-up service was freed from subscription fees. Calculation of its statistics is currently based on the number of entries made through the dialed number 122. Thus, dial-up statistics became

(1) Saeed, Hayel. GIS Department, PTC, personal communication, April 16th, 2014.
(2) Saeed, Hayel. GIS Department, PTC, personal communication, Mar 18th, 2014

(3) Al-Wadee, Assem. PTC, Pers. communication, March 23rd 2014.

statistics of the numbers of entries and not of the number of subscribers. Therefore, dial-up statistics were eliminated from the research scope and ADSL was selected (AbdulRazzaq, 2014)[4].

Although YemenNet and Tele-Yemen offer ADSL services, the professionals at PTC mentioned that Tele-Yemen focuses mainly on satellite and ADSL services, which they offer as resellers of YemenNet ADSL services. In addition, the number of Tele-Yemen subscribers is incomparable to that of YemenNet subscribers. Thus, YemenNet was chosen as the provider (Al-Wadee, 2014)[5].

4.2.1.2 Physical Dimension Scope

The physical dimension scope will be determined in the following stages.

a. Determining the Highest Density Exchange

The subscriber/user density of the YemeNnet ADSL service in each exchange in Sana'a was calculated. The results are shown in Table (3).

Table 3. Density of YemenNet ADSL subscribers/sq km. (Ref: researchers)

No.	Name of exchange	Area (sq km)	No. of subscribers	Subscribers/ Sq km
1	Al-Tahrir	4.15	5533	1333
2	Dhahr Himyar	2.13	1224	575
3	Al-Safiah	10.74	8699	810
4	Al-Awqaf	4.65	3039	654
5	Hyael	27.59	13141	476
6	Shou'oub	14.27	7343	515
7	Sa'wan+ Bani Hisheish	28.09	2677	95
8	Bir Obaid	31.44	7702	245
9	Al-Asbahi+ Beit Baws	13.96	6230	446
10	Haddah	23.54	7207	306
11	Madhbah	12.64	3355	265
12	PTC-AlGiraf	31.75	4860	153
13	Al-Rawdhah+ Al-Hitarish+Sarif	53.33	1802	34
14	Al-Matar	42.12	850	20
15	Garyat Al-Rawdh	68.2	367	5

Table (3) shows that Al-Tahrir exchange is the largest exchange in terms of YemenNet ADSL subscription density with 1333 subscribers per sq km. Al-Safiah Exchange comes next with 810 subscribers per sq km, and Al-Awqaf comes third with 654 subscribers per sq km. The exchange with the lowest subscriber density is Garayat Al-Rawdh Exchange with 5 subscribers per sq km only. Despite being the exchange with the highest number of subscribers, Hayel Exchange is the sixth highest in subscriber density.

In addition, as Fig. (10) illustrates, the comparison of the ADSL highest density (Al-Tahrir exchange) with the center of gravity of population in Sana'a based on the last xensus of 2004 (Al Harazy, 2011)[6], the population and internet subscriptions are synergistic. Thus, CS and PUS are synergistic. This finding further confirms on a local scale the synergy that was mentioned on the global, regional, and national scales.

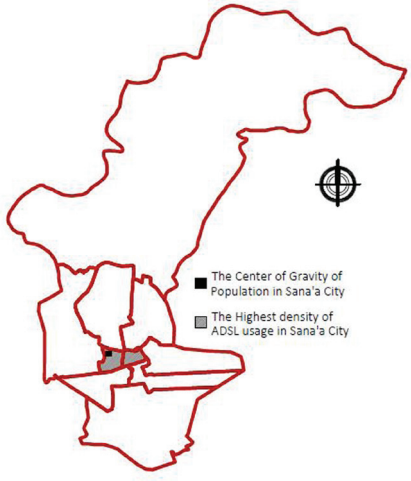

Figure 10. Yemen locational map. Synergy between the CS and the PUS in Sana'a. (Ref: Al Harazy (2011)[7], researchers)

From the above, a selected urban fabric within the boundaries of Al-Tahrir exchange will be chosen for the model application. This selection will take place in the following section.

b. Determining the Highest-density Cabinets in Al-Tahrir Exchange

- **General Description of Al-Tahrir Exchange Urban Fabric**

The urban fabric of Al-Tahrir exchange [Fig. (11)] covers an area of 4.15 sq km, and

(4) AbdulRazzaq, Bilal. Marketing Section, PTC, person. communication, March 31st 2014.
(5) Al-Wadee, Assem, PTC, person. Communication, March 23rd, 2014.
(6)Al Harazy, Samah. 2011, Ibid, pp. 69.
(7) Al Harazy, Samah. 2011, Ibid, pp. 69.

includes the traditional Sana'a (Old Sana'a, Ga'a Al-Ululfi, and Bir Al-Azab) within its boundaries. It is an area with a high diversity in land use and different urban typologies layered upon and intermingled with each other.

Figure 11. Aerial photograph of Al-Tahrir Exchange urban fabric. (Ref:[8],[9])

• Geographical Divisions of Al-Tahrir Exchange (Al-Tahrir Cabinets)

According to the Administration of Customer Services (AlTahrir Branch) and the GIS Department of PTC, Al-Tahrir exchange is divided technically into 56 cabinets. Three of these cabinets are geographically included within other cabinets. Thus, a total of 53 geographically distributed cabinets exist. These cabinets cover specific geographical areas in the exchange [Fig. (12)].

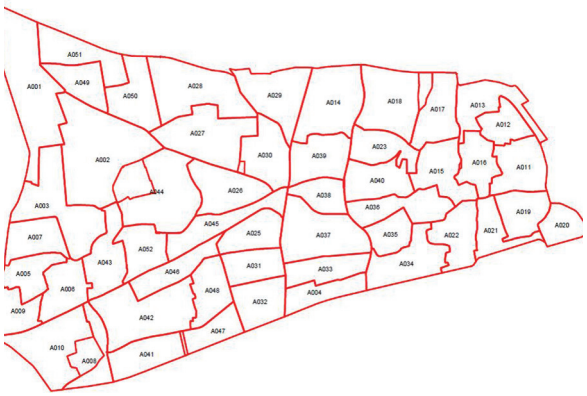

Figure 12. Cabinets of Al-Tahrir exchange. (Ref:[10])

(8) Google earth V 7.1.2.2041, (August 12th 2013), 15o 21›15.85» N, 44o12›21.52»E, Eye alt 6.16 km, Digital Globe 2014, http://www.earth.google.com (viewed August 5th 2014)
(9) Abdo, Hayel. GIS Department, PTC, person. Communication, Mar 18th 2014.
(10) Saeed, Hayel. GIS Department, PTC, person. communication, April 14th 2014.

• Statistics of Al-Tahrir Exchange

ADSL services and other related communication statistics (fixed landline statistics) are presented in the following.

• Fixed Landline Statistics

The latest fixed landline statistics (prepared lines and used lines) provided by Al-Tahrir Exchange (Center of Customer services) to the researchers were dated July 2013. They are presented in Figures (13) and (14).

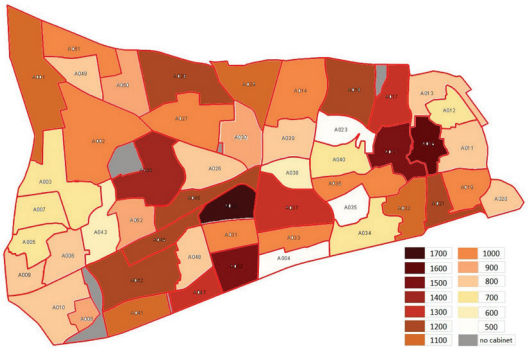

Figure 13. Prepared landlines in Al-Tahrir exchange. (Ref: Saeed (2014)[11], reserachers)

Figure 14. Working landlines in Al-Tahrir Exchange. (Ref: Saeed(2014)[12], researchers)

The prepared line map in Fig. (13) indicates the speculations for demand by PTC and thus the provision of prepared lines based on these speculations. It also provides a more accurate indication of the demand and usage of fixed landlines [Fig. (14)].

Therefore, the highest areas of use in Al-Tahrir Exchange of landlines are concentrated;

(11) Saeed, Hayel. GIS Department, PTC, person. communication, April 14th 2014.
(12) Saeed, Hayel. GIS Department, PTC, person. communication, April 14th 2014.

the densely commercial spatial activities are located with more than 1000 working lines in each cabinet [Fig. (14)]. In the Old City, the center of the Suq (Al-Zumur) has the highest working lines. The high density gradates southwards along Suq Al-Milh toward Bab Al-Yemen. Outside the Old City, usage is concentrated in the south of Al-Tahrir exchange toward Al-Zubeiry Street. A high usage is also observed in the northwestern areas, where Al-Kuwait Hospital and residential compound for doctors are located. In addition, a high usage is observed in the northern central part of the cabinet around the Bab Shou'oub area.

- **YemenNet ADSL Statistics of Al-Tahrir Cabinets**

The latest statistics on the number of subscribers in the different cabinets of Al-Tahrir exchange to YemenNet ADSL service given to the researchers were the statistics of December 31, 2012 [Fig. (15)]. Unlike the fixed line statistics, the highest numbers of subscriptions are located in the newer parts of the exchange outside the Old City, and the subscriptions are higher in the south-west of the exchange. Cabinet 47 has the highest number of subscribers (124 subscribers). Cabinet 41 to its west follows with 102 subscribers, then Cabinet 32 to its east with 94 subscribers. The northwestern Cabinets 1 and 2 follow with 81 subscribers each.

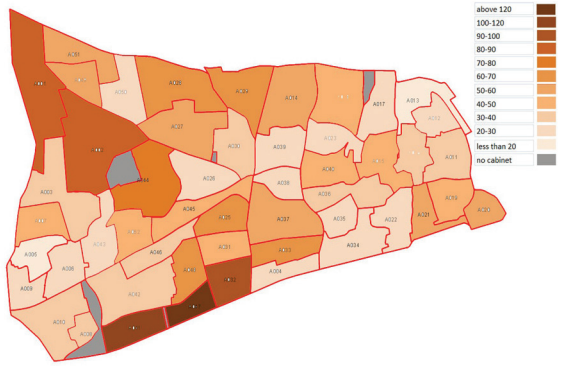

Figure 15. ADSL subscribers' distribution in AL-Tahrir exchange (by total number). (Re Saeed (2014)[13], researcher)

The subscriber/area densities of the cabinets of Al-Tahrir exchange were calculated and are presented in Fig. (16). The cabinets with the highest numbers of subscribers also have the highest subscriber densities. Cabinet 47 has the highest density with 30 persons/hectare. Cabinet 41, which has a density of 16 persons/hectare density, with approximately 50% difference, but still higher than that of the other cabinets. Cabinet 32 then follows with a density of 15 persons/hectare.

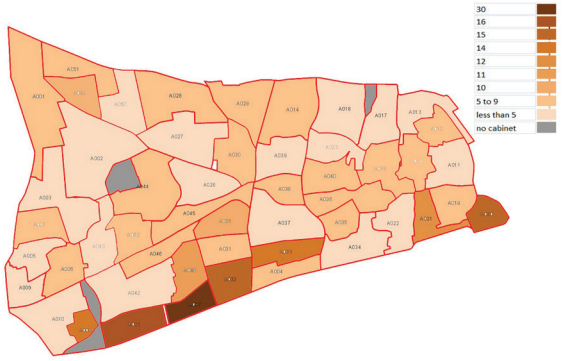

Figure 16. ADSL subscribers' distribution in Al-Tahrir Exchange (by density). [Ref: Abdo (2014),[14] researcher]

Thus, the urban fabric of the three densest cabinets, namely, Cabinets 32, 41, and 47, was selected for the model.

4.2.2 Preparation and Observation Stages

The urban fabric of Cabinets 32 and 47 was located in Neighborhood No. 511. Cabinet 41's urban fabric is divided between Neighborhoods 511 and 514 (MoM, 2014)[15]. The maps of Neighborhoods 511 and 514 were collected and compared with Google Earth (Version 7.1.2.2014) aerial photographs for more recent alterations, which may have occurred since the last updates of the maps. The blocks of each of cabinet's urban fabric were alphabetically numbered (from A to M in Cabinet 32, from A to H in Cabinet 47, and from A to E in Cabinet 41). The land uses in each block were numbered. Then, the tables for documenting the observations were prepared. The selected urban fabric was visited between June 1 and 15, 2014. The needed data were collected during this period. Ambiguities in the land uses were clarified by inquiring from residents and workers in the urban fabric.

4.2.3 Assessment Stage

The applicability of the upgrading modes to the different land uses was assessed [Table (4)].

(13) Sayeed, Hayel. GIS Department, PTC, person. communication, May 27th 2014.

(14) Abdo, Hyael. GIS Department, PTC, Person. Communication, May 27th 2014.

(15) Al-Tahrir Office, Ministry of Municipalities, person. Communication, May 28th 2014.

Table 4. Assessment of applicability of Upgrading Modes to the land uses. (Ref: researchers)

No.	Classificatioin of land use	Type of Spatial Activity	Physical/non-physical basic sptial activity	Potential upgrading modes+spatial implications									Potential Social upgrading modes+spatial implications								
				EMA	GM	EMB	S1	S2	GS	GM	ES	GM	EMA-Social	GM	EMB-Social	S1	S2	GS-Social	GM	ES-Social	GM
1	House/Apartment	Residential	physical								O	O								O	O
2	Cosmetices shop Medical equipment shop Mobile phones shop Glass shops Watches Trading agency Clothing shop Honey shop Eyeglasses shop Home appliances shop Construction materials shop Keys shop Sports equipment center Sewing appliances shop Fire extinguishing systems Audio recordings shop	Commercial	physical-non physical	O	O	O	O		O	O	O	O			O	O		O	O	O	O
3	Govermental office	Political - administrative	physical-non physical			O	O		O	O	O	O			O	O		O	O	O	O
4	Embassy	Diplomatic-administrative	physical-non physical			O	O		O	O	O	O			O	O		O	O	O	O
5	School Educational institution	educational	non physical	O	O	O		O	O	O	O	O			O		O	O	O	O	O
6	Bank Money Exchange Shop	financial services	non physical	O	O	O		O	O	O	O	O			O		O	O	O	O	O
7	Grocery Shop Patiesseire Herbs and Spices Shop Honey shop Dates shop Distilled water shop	food-commercial	physical non-phsycial	O	O	O	O		O	O	O	O			O	O		O	O	O	O
8	Restaurant Cafeteria	food services	physical	O	O						O	O								O	O
9	Mosque	Religious services	physical	O	O								O	O							
10	Laundry	Physical personal services	physical	O	O						O	O								O	O
11	Carpenter	physical craftmenship	physical	O	O						O	O								O	O
12	Barber Shop	Physical personal services	physical	O	O						O	O								O	O
13	Photo Studio	Physical personal services	physical	O	O						O	O								O	O
14	Magazine Store	cultrual services	non-phsycial	O	O	O	O		O	O	O	O			O	O		O	O	O	O
15	Internet Café	Virtual services	non physical	O	O	O	O		O	O	O	O			O	O		O	O	O	O
16	Call Center	communication services	physical	O	O						O	O								O	O
17	Health Institution	Health-administrative services	physical non-phsycial	O	O	O		O	O	O	O	O			O		O	O	O	O	O
18	Doctor's Clinic	Health services	physical	O	O						O	O								O	O
	X-Ray Center																				
19	Charity Institution	financial/social services	physical non-phsycial	O	O	O		O	O	O	O	O			O		O	O	O	O	O

No.	Classificatioin of land use	Type of Spatial Activity	Physical/non-physical basic sptial activity	Potential upgrading modes+spatial implications									Potential Social upgrading modes+spatial implications							
				EMA	GM	EMB	S1	S2	GS	GM	ES	GM	EMA-Social	GM	EMB-Social	S1	S2	GS-Social	GM	ES-Social	GM
20	Hotel	Rental residential services	physical	O	O						O	O								O	O
21	Attorneys office	Financial/legal/ linguistic services	physical non-phsycial	O	O	O		O	O	O	O	O			O		O	O	O	O	O
	Financial services offices																				
	Translation office																				
22	Travel Agency	travel services	non physical	O	O	O		O	O	O	O	O			O		O	O	O	O	O
23	Air Cargo	Shipping services	physical non-phsycial	O	O	O	O		O	O	O	O			O	O		O	O	O	O
24	Sign Writer	Calligraphic services	physical	O	O						O	O								O	O
25	Storage	Storage	physical								O	O								O	O
26	Park	recreational/ social services	physical	O	O						O	O	O	O						O	O

● **EMA upgrading mode** was applicable to all the land uses, with the exception of the residential land uses governmental, embassy, and storages, which do not (from the point of view of the researchers) need to be advertised or benefit from them. Movement is generated (GM) toward the land uses, in which EMA is applicable. EMA social upgrading mode was applicable to only two of the land uses, the park and the mosque, as these are considered the only land uses for public "third places" or "social spaces" and would benefit from the widening of the knowledge of their existence.

● **EMB upgrading mode** was applicable to the land uses, which included or depended on non-physical spatial activities. The land uses whose spatial activities depend on physical and non-physical spatial activities had the potential for partial substitution (S1). Examples of these land uses are as follows: government offices, embassy, commercial services, and magazine stores. The social spaces would benefit from the widening of the knowledge of their existence. Land uses, which are wholly non-physical, have the potential of absolute substitution (S2) in CS, for example, administrative private institution, charity institution, attorney's office, translation office, travel agency, educational institution, and financial institution. S1 and S2 are potentials for the generation of needed physical land uses (GS), and EMB-social is one form of space that can be generated based on them.

EMB upgrading mode is not applicable to land uses whose spatial activities depend on physical needs and cannot be overtaken by virtual spatial activities in CS. Examples of these land uses are as follows: house or apartment, restaurant, cafeteria, laundry, barber shop, doctors' clinic, X-ray center, hotel, carpentry shop, photo studio, call center, media advertising office, storage, park and mosque.

● **ES upgrading mode** was applicable to all land uses with the exception of the mosque. All land uses, except the mosque, benefit from adding other virtual spatial activities in CS in addition to the original spatial activity in PS, thereby further utilizing the PS and increasing its significance. For example, the residential land use can benefit from more spatial activities of the virtual level (work and leisure in CS) as it may also lead to generation of movement (GM) based on these new spatial activities.

The mosque is considered by the researchers to be spiritual land use, which bonds the physical and spiritual aspects of a person with Allah Almighty and with other people, and should not be distorted with any other spatial activities. ES leads to GM in PS toward land use. Wherever ES is applicable, ES social is applicable as one form of virtual spatial activities that can be added to the original spatial activity.

4.2.4 Analysis Stage

The analysis of the upgrading modes was conducted in accordance with the assessment stage. First, the land uses of the selected urban fabric were visually presented on maps. Then, the upgrading modes were projected on the land uses. Finally, the quantitative analysis of the upgrading modes was calculated. This procedure will be presented in the following sections.

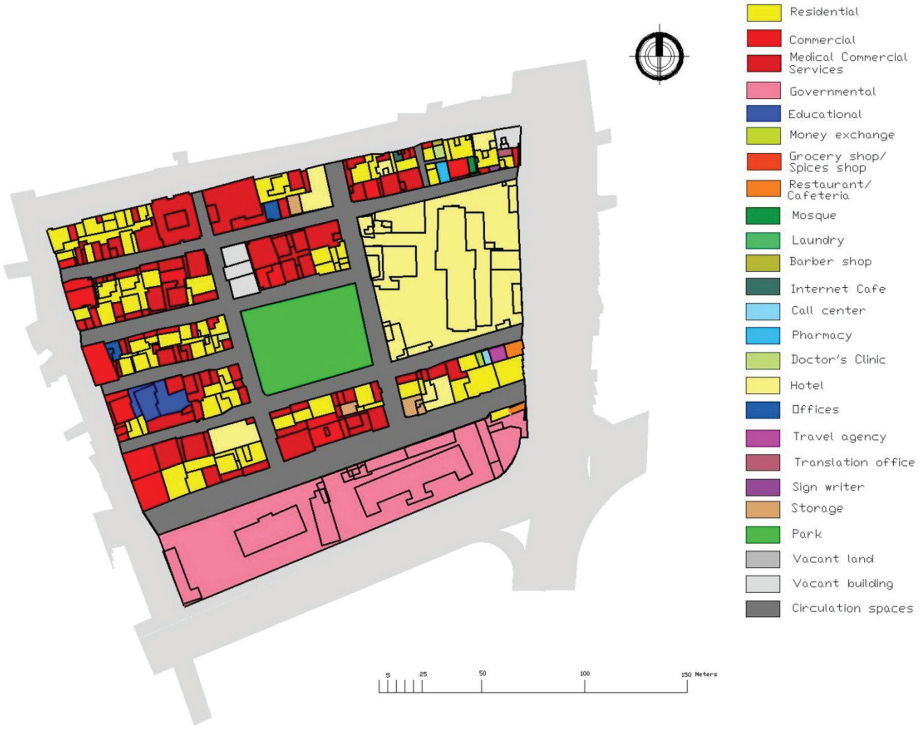

Figure 17. Cabinet 32 urban fabric land uses. (Ref: researchers).

4.2.4.1 Land Use Projections

The land uses were projected on the maps of the urban fabrics of the three cabinets as follows:

i. Cabinet 32 Urban Fabric

The urban fabric of Cabinet 32 follows the gridiron type and covers an area of approximately 55,687 sq m. The land uses and their areas are projected in Fig. (17) and Table (5).

Table 5. Land use areas and their percentages in the urban fabric of Cabinet 32 (Ref: researchers)

Land uses in Cabinet 32	Area of land uses (sq m)	Percentages of land uses/total area
Inner circulation spaces	12,834	23.9%
Residential	6,974	12.9%
Commercial	10,830	20.2%
Hotels	8,617	16.1%
Government	8,524	15.9%
park	3,387	6.3%
Other land uses	2,521	4.7%
Total	53,687	100%

Figure (17) and Table (5) show that the urban fabric of Cabinet 32 is a highly commercial area (the commercial land use occupies approximately 20% of the total area). Most of the commercial activity is focused on medical supplies and equipment. However, in many cases, the commercial land use occupies the ground floor of the building, and the remaining floors are used for residential land use. The government and hotel areas cover 16% each, and the residential land use covers 13% of the urban fabric.

The general environment in the cabinet's urban fabric is the quietest of the three cabinets because of the specialized nature of its commercial activities, as well as the fact that its movement spaces are not typically used for passing through to other areas around it. In addition, the park at the heart of the cabinet is lively and active during the afternoon with children and women and adds a sense of warmth to the area, which is pleasant and different from the rest of the city.

ii. Cabinet 47 Urban Fabric

Cabinet 47 is located to the west of Cabinet 32 and covers an area of approximately

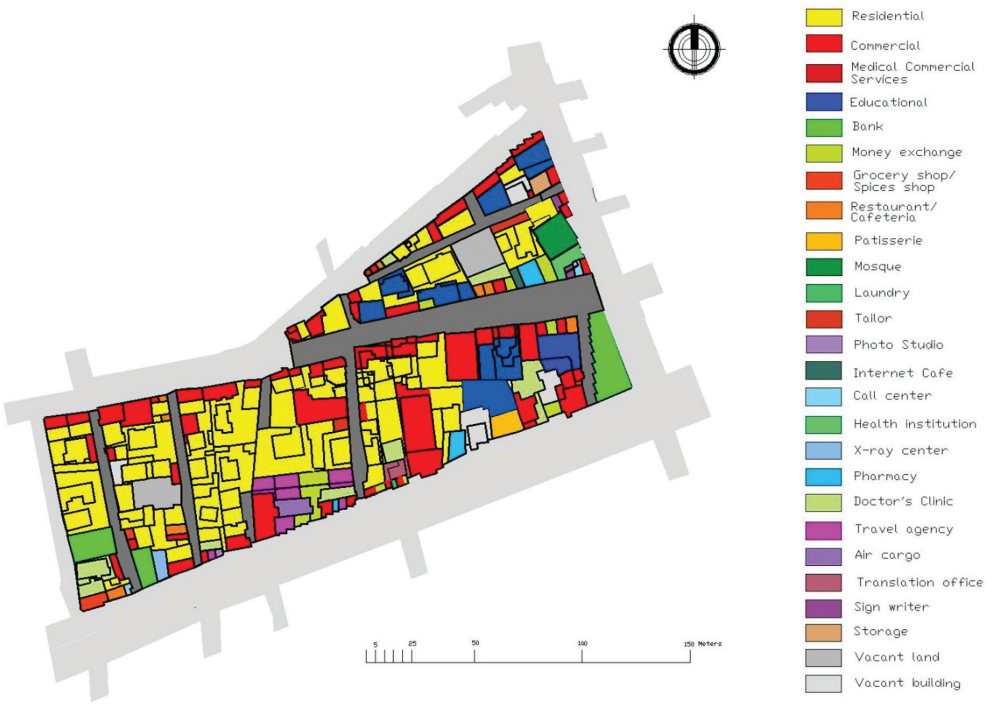

Figure 18. Land uses of the urban fabric of Cabinet 47. (Ref: researcher)

35,653 sq m. In addition, its typology is different from that of Cabinet 32's urban fabric, which has a more traditional typology; this difference is most clear in the borderlines of the blocks and the orientations of the buildings. The typology and land uses of the urban fabric of Cabinet 47 are shown in Fig. (18). The areas and the percentages of the land uses are shown in Table (6).

As shown in Fig. (18) and Table (6), a wide variety of land uses exist in the urban fabric of Cabinet 47, which may be due to its location between the two main streets, namely, Al-Qasr Street in the north and Al-Zubeiry Street in the south. Despite this diversity, the residential area covers approximately 36% of the area of the urban fabric. The circulation spaces cover 17%, and the commercial area covers approximately 17%. The residential land use is located mostly at the centers of the blocks and is surrounded by the non-residential land uses overlooking the main streets, especially the commercial areas. Therefore, the residential land use appears to have been swallowed by the other non-residential land uses and is thus the reason for the different impression a visitor gets between the active lively crowded environment at the peripheries and the quiet environment at the inner parts of the blocks.

The streets at the north of Cabinet 47's urban fabric are highly used vehicle passages, which link the north-south branch of Al-Qasr Street with Al-Ga'a and Al-Zubeiry Streets. These streets mostly have commercial mobile phone and clothing shops. The land uses in the east of the cabinet are diverse and non-residential, and they include commercial land use, offices, Al-Arabi Bank, a mosque, and other services, such as cafeterias, call centers, and money exchange shops.

Table 6. Land use areas and their percentages in the urban fabric of Cabinet 47 (Ref: researcher)

Land uses in Cabinet 47	Area of land it occupies (sq m)	Percentages of land uses/total area
Inner circulation Spaces	6,097	17.1%
Residential	12,850	36.0%
Commercial	6,168	17.3%
Offices	2,177	6.1%
Banks	1,229	3.4%
Travel agencies	588	1.7%
Doctors' clinics	1,239	3.5%
Vacant land and Buildings	1,660	4.7%
Other land uses	3,645	10.2%
Total	35,653	100%

The land uses of the buildings that overlook Al-Zubeiry Street in the South are more diverse because of the importance of Al-Zubeiry Street as a main artery in the city. The street includes banks, travel agencies, pharmacies, restaurants, money exchange shops, call centers, and other land uses, which densely occupy the ground floors of the buildings. The upper stories are occupied by doctors' clinics, lawyer offices, translation offices, other types of offices, and some institutions. Located between the northern and southern land uses overlooking Al-Qasr and Al-Zubeiry, the area is surprisingly occupied by quiet residential areas. No open or social spaces such as parks are found in Cabinet 47. New high-rise buildings have been recently built in the area.

iii. Cabinet 41 Urban Fabrics

Cabinet 41 is located in the west of Cabinet 47 and has a similar urban fabric typology with a larger area of approximately 56,940 sq. m; its urban f abric differs in the narrow roads that sometimes lead to open spaces enclosed between the buildings of the urban fabric, especially in the west.

Considering its central location, Cabinet 41 is also sandwiched between the two densely occupied streets in the city, namely, Al-Qasr Street western end, which leads to Al-Ga'a area in the north of the cabinet, and Al-Zubeiry Street in the south. The land uses of its urban fabric are shown in Fig. (19), and the percentages of the land uses are shown in Table (7).

Despite the evident variety of the land uses in Fig (19), the residential land use has the highest percentage of 36.3% [Table (7)]. The inner circulation spaces come next with 19.3%. The Chinese embassy covers a significant 17.3% of the urban fabric, followed by commercial land uses with 15.2%.

Table 7. Land use areas and their percentages in the urban fabric of Cabinet 41 (Ref: researchers)

Land uses in Cabinet 41	Area of land it occupies (sq m)	Percentages of land uses/total area
Inner circulation Spaces	10,987	19.3%
Residential	20,646	36.3%
Commercial	8,665	15.2%
Embassy	9,838	17.3%
Offices	846	1.5%
Educational	1,062	1.9%
Travel agencies	533	0. 9%
Other land uses	4363	7.6%
Total	56,940	100%

Figure 19. Cabinet 41 urban fabric land uses. (Ref: researchers)

The land uses overlooking Al-Qasr Street are mostly commercial with the exception of the Chinese embassy. The commercial land uses here are mostly clothing and gift shops; some of them occupy the entire building, and others occupy the ground floor, leaving the rest of the building for residential land use. The land uses overlooking Al-Zubeiry Street are denser and diverse, as can be seen in Fig. (19). In this cabinet, most of the north-south axis streets are used for commercial activities and residential purposes, especially the street in the far west of the cabinet, which is a vital passageway from Haddah to Al-Ga'a and beyond it for those heading north in the city.

4.3 Potential of CS Upgrading Modes on the Selected Urban Fabric

In accordance with the assessment stage, the upgrading modes were projected on the land uses of the urban fabric of the three cabinets. The area percentages of each of the potential upgrading modes were calculated. The percentages are clarified as follows:

- **Cabinet 32 Urban Fabric**

The projection of the upgrading modes assessed in Table (4) obtained the following results in Cabinet 32:

1. EMA and EMA Social

The potential of EMA upgrading mode on Cabinet 32's urban fabric is shown in Fig. (20).

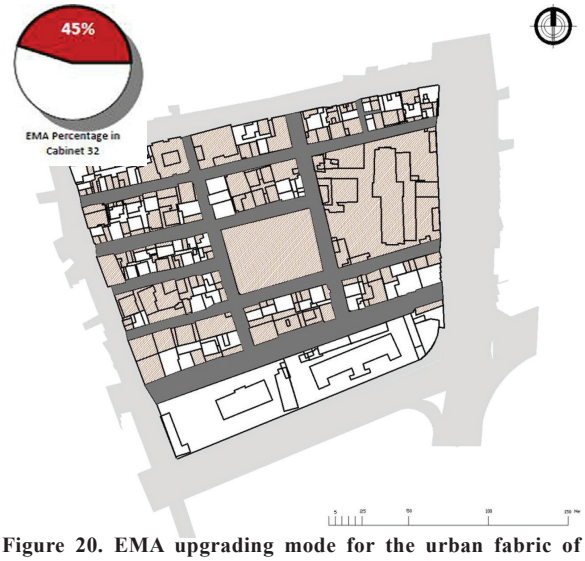

Figure 20. EMA upgrading mode for the urban fabric of Cabinet 32. (Ref: researchers)

Figure (20) shows that 45% of the urban fabric of Cabinet 32 has the potential to be generally upgraded through the EMA upgrading mode. Therefore, 45% of the urban fabric can be advertised through CS. Consequently, 45% of the urban fabric can generate movement toward it through EMA. The social performance upgrade through the EMA social upgrading mode drops to 6.5%, because EMA social depends on advertising social spaces in the urban fabric to increase their significance and generate movement toward them. The land uses, which can be considered social spaces in Cabinet 32's urban fabric, were the park and the mosque, which constitute 6.5% of the urban fabric total area. EMA social is presented in Fig. (21).

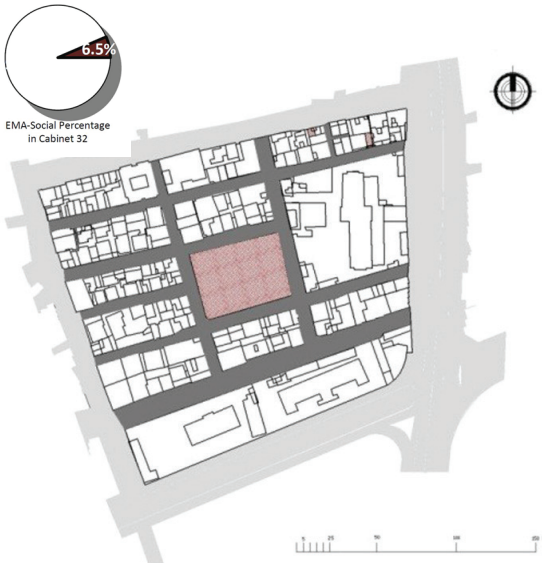

Figure 21. EMA social upgrading mode for the urban fabric of Cabinet 32. (Ref: researchers)

2. EMB and EMB Social

Thirty-eight percent of the urban fabric in Cabinet 32 can be upgraded through the EMB upgrading mode as presented in Fig. (22).

This urban fabric can be enhanced by virtual spaces in CS, in which their virtual spatial activity (VSA1) can substitute for some or all of the physical spatial activity (PSA1). According to the assessment stage, 38% of the urban fabric has the potential for partial substitution by virtual spaces in CS. Six percent of the urban fabric has the potential for absolute substitution. Therefore, this is a potential area for the generation of needed physical spaces in the urban fabric.

EMB social comes in the same physical level as social spaces, which can be generated as a portion of the potential physical spaces generated. This finding indicates a potential increase of up to 38% in inclusion in PS for social activity. It also means up to 38% increase in the connectivity within this urban fabric by generating movement for social purposes in PS toward them [Fig. (22)].

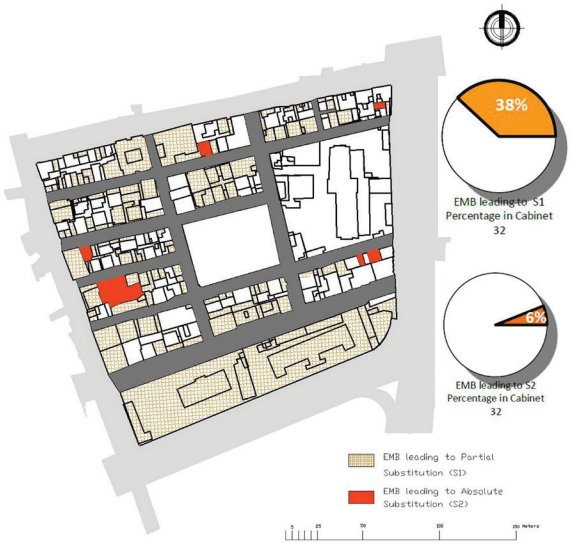

Figure 22. EMB and EMB social upgrading modes of the urban fabric of Cabinet 32. (Ref: researchers)

3. ES and ES-Social

As shown in Fig. (23), 75% of the urban fabric, which is approximately 99% of the land uses, have the potential to be upgraded through ES upgrading mode. These spaces can foster other spatial activities in the form of virtual spaces in CS (VSA2, VSA3, and VSA4). Thus, this mode is a flexible way of compensating for the shortages in the urban fabric, there by maximizing the effective usage of the land on the physical level.

With regard to the upgrading of the social performance through ES, any of the spaces in ES can foster social spatial activity. Thus, a potential for a 75% increase in inclusion on the virtual level (CS) exists, as well as a 75% increase in the connectivity in the physical level because of the generation of movement toward the physical spaces it is leveled upon.

- **Cabinet 47 Urban Fabric**

The upgrading modes for the urban fabric of Cabinet 47 are as follows:

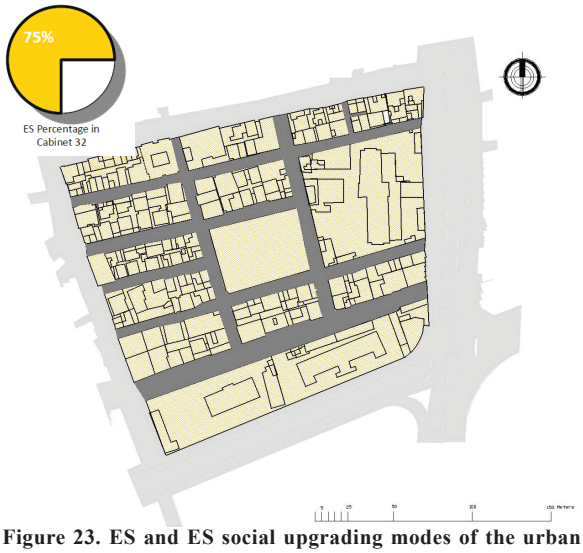

Figure 23. ES and ES social upgrading modes of the urban fabric of Cabinet 32. (Ref: researchers)

1. EMA and EMA Social

The potential of the EMA upgrading mode on Cabinet 47's urban fabric is shown in Fig. (24).

As seen in Fig. (24), 43% of the urban fabric of Cabinet 47 has the potential to be generally upgraded through the EMA upgrading mode. Consequently, 43% of the urban fabric can generate movement toward it through EMA.

Social upgrading through EMA-social drops to only 0.1% for the land uses, which can be considered social spaces in the cabinet; this social space includes only one mosque. The EMA social upgrading mode is presented in Fig. (25).

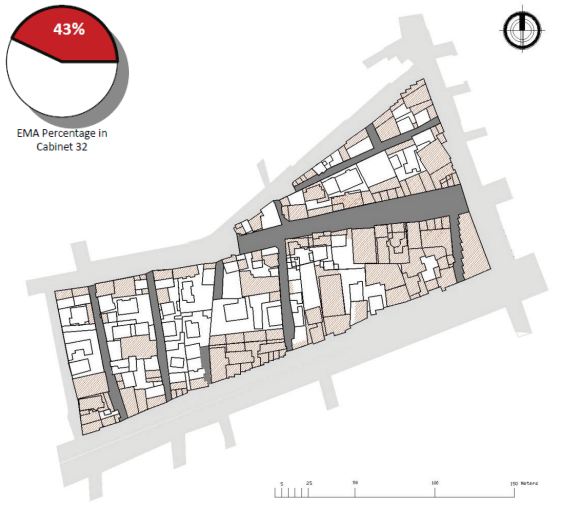

Figure 24. EMA upgrading mode of the urban fabric of Cabinet 47. (Ref: researchers)

Figure 25. EMA social upgrading mode for the urban fabric of Cabinet 47. (Ref: researchers)

2. EMB and EMB Social

A total of 40% of the urban fabric in Cabinet 47 can be upgraded through the EMB upgrading mode. More specifically, 40% of the urban fabric has the potential for partial substitution by virtual spaces in CS, and 15.3% has the potential for absolute substitution. Needed physical spaces can be generated based on this substitution, thereby generating movement toward them in PS.

With regard to EMB social upgrading, social spaces can be generated as a portion of the potential 15.3% to 40% physical spaces generated, which leads to an up to 40% increase in inclusion on PS for social activity, and leads to an up to 40% increase in the connectivity within this urban fabric by social movement generated because of these spaces. The EMB and EMB social upgrading mode projection on the land uses is shown in Fig. (26).

Figure 26. EMB and EMB social upgrading modes for the urban fabric of Cabinet 47. (Ref: researchers)

3. ES and ES Social

The potential of the ES and ES social upgrading modes on the urban fabric of Cabinet 47 is shown in Fig. (27).

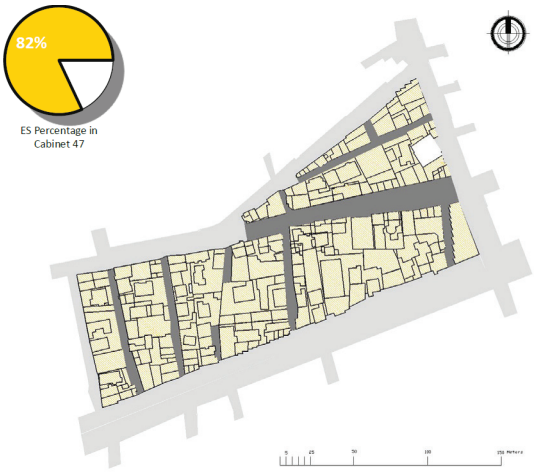

Figure 27. EMA social upgrading mode for the urban fabric of Cabinet 47. (Ref: researchers)

Figure (27) shows that 82% of the urban fabric, which is approximately 99.9% of the land uses, has the potential to be upgraded through the ES upgrading mode. With regard to the upgrading of the social performance through ES social, any of the spaces in ES can foster social spatial activity. Thus, a potential for an 82% increase in inclusion on the virtual level (CS) may exist, as well as an 82% increase in the connectivity on the physical level due to the generation of movement toward the physical spaces it is leveled upon.

- **Cabinet 41 Urban Fabric**

The projection of the upgrading modes obtained the following results in Cabinet 41:

1. EMA and EMA social

Twenty-four percent of the urban fabric of Cabinet 41 has the potential to be generally upgraded through the EMA upgrading mode. Consequently, 24% of the urban fabric can generate movement toward it through EMA.

EMA social drops to only 0.7%. The land uses, which can be considered social spaces in the cabinet, were one mosque and an enclosed open space in the northeastern part of the urban fabric. A visit to the location showed that this open space was used for social purposes. The EMA and EMA

social upgrading modes are presented in Figs. (28)– (29).

Figure 28. EMA upgrading mode of the urban fabric of Cabinet 41. (Ref: researchers)

Figure 29. EMA social upgrading mode for the urban fabric of Cabinet 41. (Ref: researchers)

2. EMB and EMB Social

The potential of the EMB and EMB social upgrading modes on the urban fabric of Cabinet 41 is shown in Fig. (30).

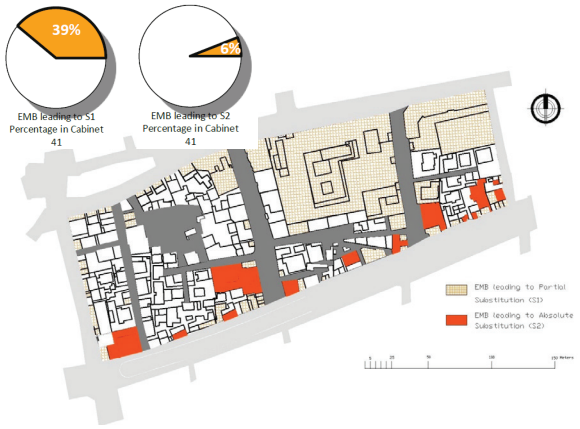

Figure 30. EMB and EMB social upgrading modes of the urban fabric of Cabinet 41. (Ref: researchers)

Figure (30) shows that 39% of the urban fabric in Cabinet 47 canbe upgraded through the EMB upgrading mode. More specifically, 39% of the urban fabric has the potential for partial substitution by virtual spaces in CS and 6% for absolute substitution, thereby generating needed physical spaces in the urban fabric movement toward them. Needed physical spaces can be generated based on this substitution, thereby generating movement toward them in PS.

With regard to the upgrading of the social performance through EMB social, social spaces can be generated as a portion of the potential 6% to 39% physical spaces generated, thereby leading to a 6% to 39% increase in inclusion on PS for social activity. It also leads to a 6% to 39% increase in the connectivity within this urban fabric by social movement generated because of these spaces.

ES and ES social: Seventy-nine percent of the urban fabric has the potential to be upgraded through the ES upgrading mode, as shown in Fig. (31).

With regard to the upgrading of the social performance through ES social, any of the spaces in ES can foster social activity by being connected to the virtual social spaces in CS. Thus, a potential 79% increase in inclusion on the virtual level (CS) exists, as well as a 79% increase in the connectivity on the physical level because of the generation of movement toward the physical spaces to which those virtual spaces are connected.

Figure 31. ES and ES social upgrading modes for the urban fabric of Cabinet 41. (Ref: researchers)

4.4 Potential of CS Upgrading Modes on Selected Urban Fabric: Mean Values

The results presented in the previous sections are summarized in Table (8). Generally, a mean value of 27% of the studied urban fabric can be upgraded by CS through the EMA upgrad-

Table 8. Potential of CS in general upgrading and upgrading of the social performance of the urban fabric of Cabinets 32, 47, and 41 (Ref: researchers)

Upgrading Mode / Urban Fabric	EMA (%)	EMA-Social (%)	EMB and EMB-Social		ES and ES-Social (%)
			EMB Partial (%)	EMB absolute (%)	
Cabinet 32's urban fabric	45	6.5	38	5.7	75
Cabinet 47's urban fabric	43	0.1	40	15.3	82
Cabinet 41's urban fabric	24	0.7	39	6	79
Mean value of upgrading modes (% of urban fabric)	27	2.4	38	9	78.7

ing mode, and 2.4% of the urban fabric can be socially upgraded through EMA social. The range can be upgraded between 9%–38% through EMB.

This percentage is a potential percentage for generating the needed land uses instead of substituted land uses, including physical social Spaces.

Finally, 78.7% can be upgraded through ES and ES social. Generally, CS has a significant potential role in upgrading and in upgrading the social performance of the studied urban fabric in Sana'a.

5. Conclusion

The theoretical approaches toward ICT-based urban change are classified into two main groups: technological determinism and non-determinism theories. Technological determinists speculated that ICTs will lead to the death of distance and of geography, thereby leading to the dematerialization of cities.

Non-determinism theories criticized the simplicity and the one-dimensionality of technological determinism, and its failure to capture urban dynamics. They believe that the relationship between technology and the urban fabric is more complex and that technology and other urban forces interact to form a new urban typology.

In addition, ICTs have been internationally recognized as an urban development tool. CS has also been recognized as a new alternative "third place." Virtual spaces have become "cyberplaces" based on the assumption that they can help to improve social organization and collective practices, as well as potentially revivify neighborhoods. As a result, many projects and initiatives based on "virtual third places" are emerging throughout the world and promoted by national governments and civil society institutions.

To satisfy the quest in the urban profession for new approaches and empirical tools, that view ICTs as enabling forces, and based on an understanding of the relationship of their spatial dimension (CS) with the urban fabric, this research presented an urban empirical tool, which linked CS and PS and presented CS as a potential upgrading tool.

This model is characterized by flexibility in its application, and it can be applied on an existing urban fabric for urban development. This model can also be applied on a hypothetical urban fabric to revisit urban planning specifications because it provides insight on how CS can and will affect the urban fabric in general.

The application of the research model in Sana'a found a synergy between CS and PUS. This finding confirms that CS synergizes to PS on a local level. The projection of the analytical model of the study shows that up to 78.7% of the selected urban fabric of Sana'a can be upgraded through the three general and three social upgrading modes of CS.

Advertising the physical spatial activities in CS through the EMA upgrading mode can increase the significance of 27% of the urban fabric, thereby generating movement toward this portion of the urban fabric and thus its connectivity with the rest of PS. Given the limited social spaces, the upgrading through the EMA social upgrading mode has the potential to upgrade only 2.4% of the urban fabric.

The second upgrading mode, EMB, presents a potential for partial substitution of 38% of the urban fabric and absolute substitution of 6%. This substitution is a potential free PS to compensate for the many shortages in the land uses in Sana'a's urban fabric; among these shortages are the much-needed social spaces.

The third upgrading mode (ES and ES social), being the most flexible and widely known upgrading mode, has the potential to upgrade 78.7% of the urban fabric. This percentage of the urban fabric generates more movements in the circulation spaces, thereby increasing the significance and utilization of these physical spaces, which can have a multitude of virtual land uses in addition to their original physical land use.

6. Acknowledgment

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الفضـــاء الأفـــتراضي و الفـــراغ المـــادي: نمـــوذج لتحســـين الأداء الاجتماعـــي للنســـيج العمـــراني (حالـــة مدينـــة صنعـــاء)

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قدم للنشر في ١٩/ ٤/ ١٤٣٨هـ؛ وقبل للنشر في ٢٠/ ٨/ ١٤٣٨هـ.

ملخص البحث. الغرض – صنعاء مثال فريد لمدينة عربية إسلامية كانت محصورة داخل أسوارها القديمة حتى أواخر الستينيات من القرن الماضي. وقد أتاح نسيجها العمراني التقليدي قدرا كبيرا من التماسك والتواصل وبالتالي جودة الأداء الاجتماعي. في السنوات الستين الماضية، توسعت المدينة من حيث الحجم والسكان. بالأضافة إلى العديد من التحولات العمرانية الأخرى أدى هذا التوسع إلى تدهور الأداء الاجتماعي للنسيج العمراني . كما شهدت صنعاء تطورات ملموسة في نظم الأتصالات ، وبدخول تكنولوجيا المعلومات والاتصالات والأنترنت أصبح اليوم الفضاء الأفتراضي حقيقة واقعة في حياة العديد من سكان المدينة. الهدف من هذه الورقة هو الإجابة عن السؤال التالي: ما هو الدور المحتمل للفضاء الأفتراضي في رفع مستوى الأداء الاجتماعي للنسيج العمراني في صنعاء؟

المنهجية – يفترض هذا البحث أن الفضاء الإفتراضي لديه إمكانات في الارتقاء بالأداء الاجتماعي. وسوف يقدم هذا البحث نموذجا يستند إلى «تطوير أنماط» الفضاء الأفتراضي للنسيج العمراني. حيث سيتم أولا عرض نماذج لأنماط التحسين العام ، والتي منها سوف تستمد أساليب رفع مستوى الأداء الاجتماعي للنسيج العمراني. **النتائج** – خلصت هذه الدراسة إلى أن صنعاء في حالة من التجزؤ الاجتماعي والتبعثرالمكاني، والفصل الطبقي وعلاوة على ذلك، فإن الفضاء الإفتراضي له حضور كبير في المدينة وقد إجتذب إهتمام الخاصة والعامة. تم تطبيق أساليب التحسين ورفع المستوى الاجتماعي على نسيج عمراني مختار في صنعاء. وتشير النتائج إلى أن أساليب رفع المستوى الاجتماعي للفضاء الإفتراضي يمكن أن تحسن من الأداء الأجتماعي للنسيج العمراني للمدينة بنسبة تصل إلى ٧٩٪. **الأصالة** – يقدم هذا البحث نموذجا تجريبيا جديدا يختلف عن كثير من الأبحاث التي تعتمد على المنهج الوصفي لرصد العلاقات المتبادلة بين الفضاء الإفتراضي والحيز المادي. كما يستكشف البحث إمكانيات الفضاء الإفتراضي في حل مشاكل عمرانية معينة (في هذه الحالة، عدم كفاية الأداء الاجتماعي للفراغ العمراني)

الكلمات المفتاحية: الفضاء الأفتراضي ، الفراغ المادي ، الفراغ العمراني ، الأداء الاجتماعي، النسيج العمراني.