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Guidelines for Sustainable Urban Mobility in Historic Districts from International Experiences

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***Abstract*—**In recent approaches to heritage conservation, the whole context of historic areas becomes as important as the single historic building. This makes the provision of infrastructure and network of mobility an effective element in the urban conservation. Sustainable urban conservation projects consider the high density of activities, the need for a good quality access system to the transit system, and the importance of the configuration of the mobility network by identifying the best way to connect the different districts of the urban area through a complex unique system that helps the synergic development to achieve a sustainable mobility system. A sustainable urban mobility is a key factor in maintaining the integrity between socio-cultural aspects and functional aspects. This paper illustrates the mobility aspects, mobility problems in historic districts, and the needs of the mobility systems in the first part. The second part is a practical analysis for different mobility plans. It is challenging to find innovative and creative conservation solutions fitting modern uses and needs without risking the loss of inherited built resources. Urban mobility management is becoming an essential and challenging issue in the urban conservation projects. Depending on literature review and practical analysis, this paper tries to define and clarify the guidelines for mobility management in historic districts as a key element in sustainability of urban conservation and development projects. Such rules and principles could control the conflict between the socio–cultural and economic activities, and the different needs for mobility in these districts in a sustainable way. The practical analysis includes a comparison between mobility plans which have been implemented in four different cities; Freiburg in Germany, Zurich in Switzerland and Bray Town in Ireland. This paper concludes with a matrix of guidelines that considers both principles of sustainability and livability factors in urban historic districts.

***Keywords*—**Sustainable mobility, urban mobility, mobility management, historic districts.

I. Introduction

URBAN conservation is a comprehensive process that integrates different aspects of the historic districts either physical or non-physical in order to ensure sustainability. Current urban conservation strategies are focusing on socio-cultural and economic aspects beside the urban improvements. Urban spaces in historic districts are an effective host for socio-cultural and economic activities; however, these spaces are supposed to function properly for mobility, inhabitants' movement, service access, goods delivery and tourists' access. Accordingly, this paper is focusing on sustainable mobility management in historic districts.

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II. Literature Review

A. Activities in Historic Districts

Most cities have historic cores which might have symbolic, political, or social meanings. Nowadays, many transformations have been occurred to these historic districts in terms of land use, activities, and used technologies in order to make historic districts suitable for contemporary life. Urban spaces were originally designed to enhance the dignity and attractiveness of the monuments and historic buildings. This is being lost in these days because of the growth of uncontrolled activities and uses [1]. Many different uses and activities are located in city centers, where historical buildings exist, such as private houses, palaces, monuments, storehouses, warehouses, cultural buildings, touristic services, headquarters of former important companies, and administrative offices like post offices [2].

B. Types of Mobility

Activities and land uses generate different types of mobility, which involve different mobility modes. The relationship between the three components is very complicated and involves many factors which need an organizational pattern for movement management to achieve satisfaction of all users of the historic districts. This relationship is affected by many factors such as mobility needs, urban form, spatial accumulation, level of development and technology [3]. There are many different modes of mobility varying from the slow pedestrians to the high-speed trains crossing by cycling, small vehicles, and large vehicles. These modes have different characteristics concerning the usage of the streets, availability for users, ride sharing type and parking needs [4]. Therefore, there are many factors that involved in the decision of using one of these mobility patterns. Such factors are related to the characteristics of the urban fabric, the socio-cultural aspects of the community, economic situation and environmental issues.

C. Mobility Problems in Historic Districts

The city is a place in which it combines a diverse complex of aspects. Nowadays, the city is not completely coherent; the urban fabric, people behavior, economic or social urban policies are developing and changing continuously. This explains the existence of problems of the infrastructure in historical districts [5]. The lifestyle and mobility nowadays are very different to those of the past ages. Therefore, the historic districts are in need for rehabilitation to cope up with the contemporary life [6].

Vehicular movement inside the historical districts affects negatively the historic buildings and context and causes big

amount of damage not only on the tangible scale but also on the non-tangible scale in terms of losing activities and living urban spaces. Air and noise pollution, vibration effects affect the quality of life and damage the materials. Change in urban context due to vehicular movement needs is a major problem, such as new bridges, traffic lights, signs and bus stops [7], [8], [4].

The pedestrian movement in historic districts is facing many problems due to narrow streets and sidewalks, the different activities on streets, street vendors, crowding, long walking distances and lack of comfort nodes [1].

Although cycling has environmental, social, and environmental benefits as it reduces the vehicular traffic and also has health benefits on the user, unfortunately it is recognized as one of the least safe modes of transportation since the lack of cycling lanes makes safety risks [9]. In addition, the historic districts were not originally designed with consideration of cycling, so there are problems such as lack of continuity of routes, street furniture creating obstacles, poor surfaces and materials used for pavement and lack of bicycle parking [10].

D. Modal Shift from Conventional to Sustainable

The transformation in concepts of mobility planning from the conventional approach to a sustainable approach requires actions to reduce the need to travel, to reduce level of car use, to encourage modal shift to green modes, to reduce trip lengths, to encourage greater efficiency in transport system with hierarchy, to be more environment-friendly, to use new technologies, to involve community and to be more economic [11].

TABLE I
CONVENTIONAL APPROACH VS SUSTAINABLE APPROACH FOR MOBILITY [12]

The Conventional Approach	The Sustainable Approach
Physical dimensions	Social/economic/ environmental dimensions
Traffic focus, particularly on cars	People focus
Large in scale	Local in scale
Street as a road	Street as a space
Motorized transport	All modes of transport, preference to pedestrian and cyclists
Economic evaluation	Multi-criteria analysis - environmental and social concerns
Travel as a derived demand	Travel as a valued activity as well as a derived demand
Speeding up traffic	Slowing movement down
Travel time minimization	Reasonable travel times and travel time reliability
Segregation of people and traffic	Integration of people and traffic

A sustainable mobility system should consider reducing levels of car use through the promotion of walking and cycling and the development of the new mobility hierarchy. This hierarchy in mobility system can be achieved through slowing down urban traffic and reallocating space of public transportation system, through parking controls and road pricing, and through making it easier to use public transportation than private cars. More space of streets is being created, as it is no longer only being occupied by vehicles or public transportation and considered as a road but also is considered as a space for people and green modes of mobility. Creative use of this space at different times of the day, night or a day weekly means also that new uses and activities can be encouraged (e.g. street markets, play zones or cultural activities). Action plans to encourage modal shift to a sustainable approach must be combined with strategies to make the best use of the new released space [13].

III. PRACTICAL ANALYSIS

A. Bray Town, Ireland

Traffic conditions have noticeably deteriorated in Bray Town over recent years because of the increased volumes of vehicles, using limited streets network, increasing car ownership ratio and creating more demand for travel [14].

Fig. 1 Satellite image for Bray Town, Ireland [15]

1) Mobility Project Vision

The Bray Development Plan has set out a strategy for a sustainable mobility to be implemented in the period from 2011 to 2017. The plan provides and manages not only the mobility in the town, but also the physical, economic and social development of the town. This plan focused on enhancing the environment of the town by providing adequate infrastructure for pedestrian, cycling, public and private transport, reducing traffic congestion, improving accessibility, encouraging the use of sustainable modes of transport, integrating land use and transportation planning in order to reduce the travel demand, reducing energy consumption, and improving quality of life [14].

2) Policy of Sustainable Mobility System

The mobility plan of Bray Town included a set of tools to achieve a sustainable mobility in the city. These tools are [14]:

a) Initiation of Management Authority

The National Transport Authority is a statutory body established in December 2009. The NTA has responsibility for the development of an integrated transport system within the Greater Dublin Area (GDA). The principal functions of the NTA with respect to the GDA are: development of an integrated accessible public transport network, promoting cycling and walking, and effective management of traffic and transport demand.

b) Integrated Land Use and Transportation Policies

The Council of Bray Town decided to implement complementary land use and transportation policies. In this regard, the NTA strategy provides development concentration along the network public transportation, maximization of existing public transport services, accessibility from neighborhood to public transport, increasing density close to public transport nodes, encouraging mixed-use developments and providing services nearby main rail station.

c) Car Parking

The policy discouraged commuter parking and encouraged to provide adequate public parking facilities to meet the short term parking requirements of local residents for shopping, business and leisure use. In addition, it focused on increasing off-street parking provision on vacant sites and reducing the number of on-street parking spaces, hence it helps to reduce congestion and improve the environment for pedestrians and cyclists. The policy included encouraging short term parking by applying a sliding scale of charges, reducing negative effects of heavy goods vehicles in the town center by considering weight and time limits, and provision of a new parking area, bus parking and bicycle spaces at the LUAS stop to facilitate interchange between the various modes of transport. The policy included the development of multi-storey buildings for car parking at different spots. These sites are suitably positioned to provide easy pedestrian access to town center businesses while avoiding additional traffic congestion on the Main Street.

d) Cycling and Walking

The policy considered that cycling and walking are cost effective, non-polluting and highly flexible transportation modes that reduce congestion. Therefore, the policy introduced a network of cycle tracks and footpaths, which formed part of an overall linked-up transportation system and provided enhanced and safe cycling and walking facilities/ infrastructure on all roads. This is promoted by training and education, and cycling as a healthy activity.

Fig. 2 Pedestrian walkways in Bray Town

Fig. 3 Luas line connecting Bray Town to Dublin area [16]

e) Public Transport

The policy encouraged and facilitated the development of an efficient, extensive, high quality, fully accessible and integrated public transport network. It supported the operation of local bus services connecting the outlying residential neighborhoods of the town with one another and with the town center. The existing local bus service was enhanced and

expanded to connect the residential areas to the town center and to the railway (DART) station; in order to allow interchange between trains and buses. In addition, it provided priority lanes for buses. The policy introduced street ticket machines and real time displays of bus arrivals to minimize the time spent by buses taking up road space. Moreover, the policy included the extension of the LUAS (tram) services to Bray, as well as supporting faster bus services. Some routes got reserved for Luas and scheduled bus services.

f) Road Development

The policy included roads development in order to facilitate and improve traffic circulation within the town center and to accommodate the increasing volume of motor traffic. The development included the removal of bottlenecks and the alteration of intersections, and improvements of mobility flows. These developments included the improvement of the signage at appropriate locations throughout the town, improving accessibility for people with mobility impairments and disabilities, introducing traffic calming measures at appropriate locations, and using proper road materials complying with different modes.

B. Zurich, Switzerland

1) Introduction

Zurich is a city that is short on space as it lies between Lake Zurich and the mountains. This requires strict spatial planning. Although the compact urban fabric makes the available streets in Zurich very little, the city is considered among the top three most livable cities in the world [17]. Fig. 4 is a satellite image for Zurich; the figure shows the limited street network in the city.

Fig. 4 Satellite image of Zurich, Switzerland [15]

2) Mobility Project Vision

In 2001, the City Council of Zurich adopted its new mobility strategy. It focused on the prevention of individual vehicles, the intelligent combination of transportation modes, pedestrian movement, cycling traffic and strategy for disabled, elderly and children [18]. The mobility management plan in Zurich aims at achieving sustainable mobility in the city by increasing use of public transportation, pedestrian and bicycle, improving the availability and attractiveness of public transportation, less use of private vehicles, and increasing the quality of public spaces [19].

3) Policy of Sustainable Mobility System

The mobility vision in Zurich has been transformed into a solid set of principles to be applied and monitored. These principles are considered as a flexible toolkit to be adapted to each local area and are known as the "house of mobility" [20].

a) Green Modes

The modal share of local traffic over the last years has continuously shifted from motorized individual transport to public transportation, cycling and pedestrians. The consequent implementation of promoting public transportation has led to simplified tariff structures (one ticket for all means of transportation). Together with prominent extensions of the public transport infrastructure, passenger frequencies on the public transportation system as well as pedestrian and bicycle trips have increased substantially in the last ten years [21]. The policy included increasing the public transportation availability, performance, quality, new designed pedestrian paths, city squares, and enhancing the quality of cycling lanes. As part of the development plan till 2030, it is expected that the city will reach an increase of a total of 60 million passengers per year on the public network. The plan includes the electrification of two lines. In this way, 2300 tons of CO_2 can be saved [19]. Fig. 5 shows an example for trams in Zurich.

Fig. 5 Trams in Zurich as a green mode of transportation

b) Promoting Sustainable Mobility Behavior

The Municipality of Zurich has offered different consulting programmes to create public awareness about sustainable mobility and to promote the use of city-friendly means of transport. The goal is to make residents aware of mobility behavior and city-friendly alternatives. This awareness aims at increasing the use of public transportation, walking and cycling while decreasing the use of private vehicles. With this level, between 2014 and 2018, it will be possible to reach a total of approximately 24,000 people (6% of the city residents). On another hand, the awareness programmes targets young people to raise their awareness about traffic issues and sustainable types of mobility at an early age to have a long-term effect on future mobility behavior and increases the acceptance of further tools to promote sustainable types of mobility [19].

c) City-Center Traffic Concept

This concept included two main actions. The first action is upgrading and adding pedestrian zone at Sihlstrasse/ Bahnhofstrasse; motorized traffic is routed Uraniastrasse. Through this change, pedestrian traffic gets more space, and the cityscape could be upgraded. Streets which previously were heavily travelled will become quieter. The second action is the renovation of the Riviera area; one lane of traffic for vehicles near the Riviera area will create space for a third row of trees. At the same time, a bicycle path can be set up for traffic in both directions, whereby bicycles and pedestrians get separate paths. A speed limit of 30 km/h is introduced in the entire project perimeter [19].

d) Parking Areas

In the late 1990s, the City Parliament has fixed the number of public parking places in the city center at the actual level, and for every building built with an underground public parking garage, a parking space within a reasonable distance on the streets had to be removed. Furthermore, a number of other instruments and parking regulations were created and applied. Trip-counting models were developed; the number of car trips is counted continuously, and restricting measures are applied when the number of these trips exceeds the agreed number. Besides a routing system for all public parking garages to reduce unnecessary search traffic, variable parking fees are applied to manage car traffic. Nowadays and within the city limits, free parking on public property has practically disappeared except in “blue zones” that are reserved primarily for residents [21].

e) Low-Speed Zones in Residential Areas

The policy included applying a city-wide program for low-speed zones in residential areas (20-30 km/h). Detailed concepts for concentrating car traffic on main roads and specific traffic routing were necessary to achieve public acceptance [21]. The reduction of the speed limit to 30 km/h was planned to be implemented on 39 communal street sections which is a further step for reducing street noise, which must be completed by 2018. As part of the mobility strategy, there are plans to reduce speed limit on main access arteries and limit the speed at night even on the network of main streets. With this, excessive street noise can be reduced. At the same time, the pedestrian safety and the quality of life have been increased [19].

f) Demand-Oriented Public Transportation

The policy depended on a demand-oriented approach. This means that the capacity of the public transportation system continuously is pro-actively adapting to the demand. In this regard, a new tramway line in Zurich’s former industrial West Side began operation in December 2011, and it is viewed as a success story for the interactive planning of transportation and land use [21].

g) Collaboration among Responsible Parties

The Department of Infrastructure and Transport is responsible for the implementation of the Mobility Strategy; however, this task can only be achieved successfully when other departments with tasks in the public sector are involved in the decision-making processes in appropriate ways. Therefore, a general awareness of the Mobility Strategy in the city administration is necessary, and common rules and instruments should be applied. The fact that the Mobility Strategy is backed by the City Council facilitated this task substantially and led to continuous and further training seminars for city employees [21].

h) Public Spaces: Functionality vs. Appearance

As soon as the public spaces in Zurich are limited, the implementation of the Mobility Strategy aims to manage traffic efficiently in a sustainable way, thus it arranges public spaces in a rather functional manner. On the other hand, the urban design of such public spaces strives for a high quality of life in terms of individual perception, aesthetics and recreation. This has to some degree opened up a field of friction and diverging interests when implementing the Mobility Strategy. In order to solve this conflict between quality and functionality, it was necessary to broadly analyze the public spaces in Zurich according to functionality, aesthetics, comfort and the quality of time spent there. A strategy for designing public spaces was then derived, and it consists of standards for the design and significance of different places in terms of a clear hierarchy and a checklist to attain a higher quality of time spent there [21]. Fig. 6 shows a limited vehicular movement in a public space in the historic district of Zurich.

Fig. 6 Management of a public space in Zurich Downtown

i) Cycling Enhancement

The mobility strategy included an extensive plan for cycling in the city. The Bicycle Master Plan strives to achieve three primary goals; increasing bicycle traffic percentage, safety for cyclists, and usage of bicycles by all people groups. Action plans have been defined; attractive and safe infrastructure for cycling comfort, improving traffic behavior by increasing awareness, firm establishment and promotion of bicycle traffic, and evaluation and checking of effectiveness. With these strategic priorities and the corresponding measures, it is planned to double bicycle traffic in the city by 2025 [19].

Fig. 7 Separate lanes and intersections for bicycles and bicycle sharing system

C. Freiburg, Germany

1) Introduction

Freiburg was heavily bombed during World War II; little remained of the city center besides the cathedral. It was decided to rebuild without altering the city's character, following the old street plan and architectural style. As the roads were rebuilt, they were widened just enough for a tram track, not for more lanes of cars. Freiburg was an early Green Movement in the 1970s. Freiburg promotes itself as a Green city and the city has won various national and international environmental awards [22].

2) Mobility Project Vision

In 1969, Freiburg adopted its first General Traffic and Transport Plan. This policy has drawn attention across the country promoting environmental-friendly modes of travel; walking, cycling and public transport [23]. Thus, in the overall traffic concept in 1989, it was set as main objective, to avoid traffic through a coordinated urban development and transport policy as possible "city of short distances" and the so-called environmental system. The remaining traffic was oriented to be environmental and city-friendly [24]. Freiburg received the first European Local Public Transport Award in 1995. Between 1982 and 1999, the volume of cycling and local public transport has increased, and car journeys has decreased [23]. The goals of the transportation plan in Freiburg were reaffirmed with the adopted in 2008; Traffic development plan VEP 2020. There are solid action-plans to achieve these objectives, including expansion of public transport, development of cycling infrastructure, improvements for pedestrian, bundling of transport axis away from the residential areas, traffic calming measures, parking management, promoting development towards the "city of short distances", ensuring the preservation of the cityscape and reducing environmental pollution [24].

Fig. 8 Satellite image of Freiburg, Germany [15]

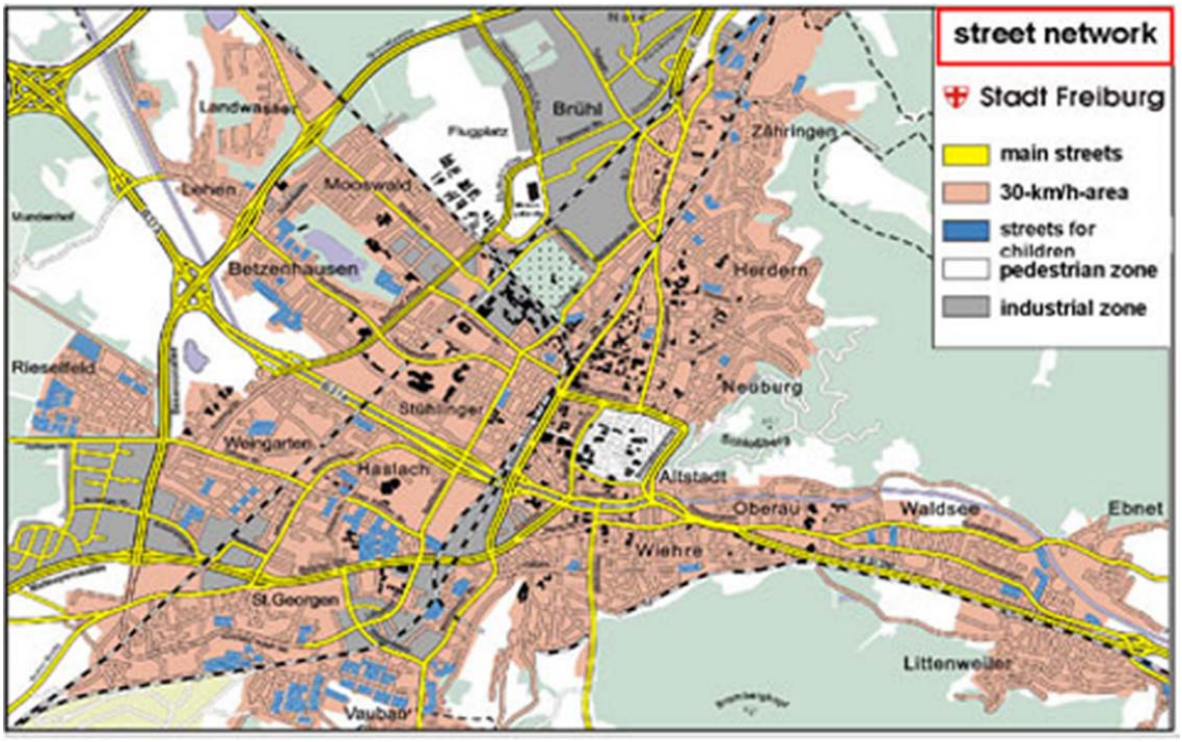

Fig. 9 Restrictions on vehicular movement in Freiburg [22]

3) Policy of Sustainable Mobility System

a) Preventive Measures to Cut Traffic

The primary goal of Freiburg plan is to cut traffic levels. This is achieved by the compact city urban fabric that can be crossed quickly, having strong local centers, developing along the main public transport arteries and giving preference to inner-city development over growth in its outskirts. All the major urban development decisions are subject to the overriding principle that traffic must be prevented [23]. In 1969, Freiburg planned its first integrated mobility plan, which aimed at improving the urban mobility while reducing motorized traffic and benefitting the environment. The plan focused on giving priority to environment-friendly modes of transport such as walking, cycling, and public transit while avoiding traffic through private vehicles use. Avoidance of traffic is achieved in conjunction with urban planning of the inner city. In 1973, the entire city center was converted to a pedestrian zone [22].

b) Environmental-Mobility-Modes

The plan included the encouragement of compatible-transport-modes with urban life and the wider environment. More than three decades of growth of the relevant infrastructures have favored walking and cycling and the use of local public transport. In 1970, there were hardly any cycling lanes. Today, approx. 420 km–long-network of cycling lanes and significantly improved facilities for cyclists including; over 9,000 bicycle parking racks and links with local public transport [23]. This mobility plan in Freiburg has focused on cycling enhancement by developing cycling paths, providing bicycle parking, bike-and-ride-system, lots at transit stations, and promoting with free maps. Between 1982 and 1999, the contribution of cycling to the city's volume of traffic increased from 15% to 27% and public transport from 11% to 18%, while distances travelled by car went down from 38% to 32%. Fig. 10 shows the modal-split of mobility modes in Freiburg during the years 1982-1999-2020 [22].

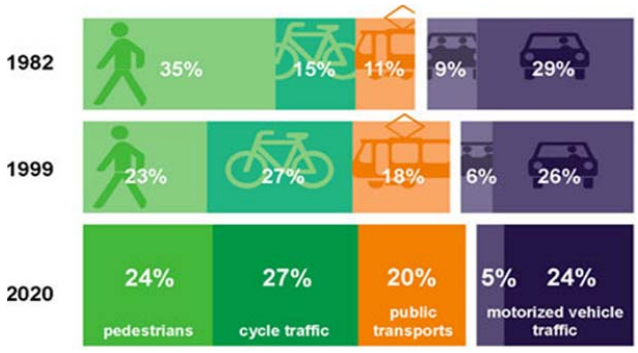

Fig. 10 Modal-split in Freiburg (1982-1999-2020) [22]

c) Parking Space Management

There is continuous management of the parking spaces in many parts of the city. A system of financial incentives and charges, multi-storey car parking and parking guidance systems relieve residential areas near the city center of motorized traffic and parking space searches. The road network is being developed further to eliminate bottlenecks in particular and to divert away from residential areas any motorized traffic that cannot be totally relocated [23].

d) Urban and Transportation Planning

The urban planning of Freiburg's inner city incorporates shopping, recreation and work in one coherent urban tissue. This functional integration should be maintained, living quality increased, the economic vitality strengthened and everything done to make the city center attractive for different users. Thus, a transportation concept for the whole city was linked with city's urban development goals and planning. The urban planning of the city was not only limited to achieve a city of short walking distances, but also included the overall townscape and urban environment to be maintained and environmental pollution generally to be reduced [25].

e) Public Transit Network

The public transit network has been steadily expanded and modernized since 1972. Nowadays, the tramway network covers 30 km and is connected to 168 km of city bus routes as well as to the regional railway system. In addition, it is walking distance for 70% of the population who lives within 500 m of a tram stop, and the trains are frequent and come every 7.5 min. during rush hours. The plan focused to make the public transport convenient, fast, reliable and comfortable along with being cheap and affordable by inhabitants. In 1984 and 1991, using trams and buses was also promoted by ticketing system. Besides this, there is a policy that any ticket for an event also serves as a ticket for public transport [22]. Fig. 11 shows the public transit network in Freiburg.

The former tram system has been converted into a modern urban light railway by the addition of new lines, increased service frequency, comfort and reaching almost all parts of the city. 65% of all residents live within the area of a stop. The urban railway between the city and the region enables good and rapid connections between the city and the region and at the main railways station links into other regional and mainline rail services [23].

f) Pedestrian Zones and Traffic Calming

Large parts of the city center are designated pedestrian zones and have been completely redesigned. After changing some areas of the inner city in Freiburg to pedestrian zone, the residential areas, around the city center were also incorporated into the traffic calming plan, which was followed eventually by all neighborhoods. With the exception of major traffic routes, all roads were converted to low speed streets or so-called play streets in the 1990s. Today, 90% of all residents live in areas with low speed for cars movement and where increased safety, reduced traffic noise, less air pollution and enhanced better environmental living qualities [25]. As shown in Fig. 9, most of streets' speed limit is 30 km/h. In other streets, in blue, cars can travel no faster than walking speed, and children are allowed to play in the streets [22].

Fig. 11 Network of public transit in Freiburg [26]

IV. Conclusion

From the previous analysis, there is a set of guidelines for a sustainable mobility system that can be followed within urban conservation projects in historic districts. Such guidelines can be adopted to local areas of intervention according to each situation. These guidelines can be extracted from the different action plans that were adopted and implemented in different historic cities concerning sustainable mobility management. The three practical studies in different settings implemented

almost the same main principles, with different adaptations for local action plans with respect to the three pillars of sustainability, including social, economic and environmental aspects.

The action plans for urban mobility in Bray Town have focused on the development of the infrastructure systems, including; development of roads, enhancing connectivity, car parking management, and signage and lighting, in addition to the enhancement of the public transportation system. In Zurich, the urban mobility plan has focused on the enhancement of the public transportation system, improving its quality and performance and making it attractive and affordable. In addition, the plan has included a system for car parking, and the enhancement of the pedestrian and cycling movement. The city of Freiburg in Germany has focused on providing priority for pedestrians and cyclists, ensuring better environment for them. Pedestrian zones in the city center with accessibility by light rail network were one of the key action plans. In addition, the plan included the enhancement of the public transportation, car parking management and roads network development. Thus, the three cities applied the general principles of sustainable mobility management. Each city has adapted these principles to suit its own condition and needs. The application of a sustainable urban mobility plan within historic cities is common in principles but it is diverse in tools and mechanisms. In general, the movement towards the green modes of mobility, including walking, cycling and public transportation is very essential in these plans, and quite suitable to the unique urban context of the historic districts

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