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The transformation of a trade fair and exhibition centre into a field hospital for COVID-19 patients via multi-utility tunnels

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ARTICLE INFO

Keywords:
Sustainable development
Multi-utility tunnel
Building adaptability
Resiliency
COVID-19
Field-hospital

ABSTRACT

This article exposes, through the case study of the IFEMA Trade Fair and Exhibition Centre in Madrid (Spain), the benefits of using a multi-utility tunnels (MUTs) system as a smart and sustainable solution for the distribution of utility networks in buildings, or in complexes made up of several buildings, to enable their quick and continuous adaptation. The saturation of the health system in the capital of Spain, motivated by the COVID-19 pandemic, forced the authorities in Madrid to improvise an emergency centre in this building. The multi-utility tunnels system was the key enabling element to deploy the necessary networks, including those for medical gases, to convert several exhibition halls into a field hospital with a maximum capacity of 5000 conventional beds and another 500 Intensive Care Unit beds, in just 100 h.

1. Introduction

A multi-utility tunnel (MUT), also called urban utility tunnel (UUT), multi-purpose utility tunnel, common utility tunnel, utility corridor or utilidor, can be defined as any system of underground structure containing one or more utility service which permits the placement, renewal, maintenance, repair or revision of the service without the necessity of making excavation; this implies that the structure is traversable by people and, in some cases, traversable by some sort of vehicle as well (APWA, 1997; Canto-Perello et al., 2013).

MUTs are an optimal long-term solution for the sustainable development of cities. They are able to solve the problem caused by the large number of utility networks, many of them out of service, that occupy the subsoil of our cities without any organisation or organisation or coordination. This phenomenon was nicknamed by some civil engineers as “the spaghetti suburface problem” (Boegly and Griffith, 1971; Curiel-Esparza et al., 2004; Curiel-Esparza and Canto-Perello, 2013; Oude, 1992). It is something that usually happens despite rationalisation and planning effort carried out by public administrations and the private sector.

The most frequent utilities that can be run inside are: water, sewage, rainwater drains, electric power (low voltage, high voltage, extra high voltage), communications, street lighting, traffic control, pneumatic waste collection systems, fuel, gas, hazardous material, district heating (or cooling) distribution, etc. In view of the results of a multitude of studies on the use of MUTs compared with the traditional burial system, it should be noted that, apart from the higher financial cost of the first installation of the utility tunnel, this new option provides a long list of advantages with regard to its usefulness and sustainability, which fundamentally will become visible along its useful life.

Among the main benefits of the use of MUTs it is possible to highlight: the execution of trenches on the roadway is avoided and therefore, the risk involved working inside; the management of waste produced by the works is optimised; the need to make patching on roads is avoided which improves their surface and aesthetic quality; the risks, inconveniences and noise produced by the works are eliminated; the risks of accidental breakage of other utilities cables and pipes are eliminated; the predictive, preventive and corrective maintenance of the networks is optimised; the breakdowns and leaks of the utility networks are reduced as they can be controlled visually; the replacement of old networks and the incorporation of new networks is facilitated; the time in repairs and rolling out of new utility networks is reduced; and the occupation of the subsoil is rationalised, since the superposition of networks is possible. (BIS, 2010; Bobylev, 2009; Broere, 2016; Cano-Hurtado and Canto-Perello, 1998; Cano-Hurtado and Canto-Perello, 1999; Hunt and Rogers, 2005; Hunt et al., 2014; ITA, 2004; ITA, 2017; Laistner, 1997; Phillips, 2016; Riera and Pasqual, 1992; Sterling et al., 2012; Valdenebro and Gimena, 2018).

Therefore, underground MUTs provide advantages and benefits for: the life cycle of the utility networks themselves; the rational use of the...
subsoil (space occupied by the utility networks); and for the quality of life and safety of the users of the public or private spaces above them. (Canto-Perello et al., 2009; Canto-Perello et al., 2016; Clé de Sol, 2005; Legrand et al., 2004).

Most of the existing MUT systems are located in the subsoil of the road space of the cities and were built at the same time as new urban developments (Canto-Perello and Curiel-Esparza, 2001; Canto-Perello and Curiel-Esparza, 2013; Glumer, 1995; Goel, 2001; He et al., 2012; Hulme and Burchell, 1999; Hunt and Rogers, 2005; Iuo et al., 2020; Phienwej, 1998; Rogers and Hunt, 2006; Yang and Peng, 2016), or also as part of the urban renewal and regeneration of historical centres (Valdenebro and Gimena, 2018; Valdenebro et al., 2019; Cui et al., 2021).

Likewise, it is also a widely used solution in large public or private complexes (universities, hospitals, airports, industrial facilities, leisure centres, exhibition centres, etc.) (Canto-Perello and Curiel-Esparza, 2013). In this case, its management is much easier because the ownership of the utility networks (from the connection point of the supplying company at the plot boundary) is linked to the ownership of the building. Its construction, control and maintenance correspond to the owner of the building complex, as the MUTs system is understood as a part of it. These tunnels often become underground pedestrian systems that connect the buildings.

In view of these advantages, it could be said that the quality of life in cities largely depends on the quality of its infrastructure. Citizens and companies demand more quantity and more quality in their services. Therefore, having more and better infrastructure is a source of sustainable competitive advantage for a territory. Furthermore, increasing importance is given to the correct use of urban underground space as a sign of the prosperity of cities, and there are even interesting proposals for it to be measured as an indicator of urban sustainability (Bobylev, 2016).

Furthermore, the correct use of the urban underground space in cities is perfectly aligned to the main objectives of the 2030 Agenda for Sustainable Development. This action plan was approved in September 2015 at the historic World Sustainable Development Summit where more than 150 heads of state and government met at the United Nations Headquarters in New York. The 2030 Agenda contains 17 goals of universal application that, since January 2016, have governed the countries’ efforts to achieve a sustainable world by 2030 (United Nations, 2019). The Sustainable Development Goals have the uniqueness of urging all countries, whether rich, poor or middle-income, to take measures to promote prosperity while protecting the planet. Goal 11 refers to Sustainable Cities and Communities and seeks to make cities and human settlements inclusive, safe, resilient and sustainable. As can be seen in this article, MUTs can contribute to this. The use of MUTs in large buildings allows their rapid adaptation in order to face unexpected or emergency situations, thus contributing to making cities safer, more sustainable and more resilient.

The main objective of this article is to expose how, the recent pandemic of COVID-19 has revealed the advantages of the organisation and rationalisation of the use of the subsoil via MUTs to serve a multi-pavilion exhibition centre. In just four days, the adaptation of two exhibition halls in the IFEMA Trade Fair Centre (Madrid) as a field hospital was possible thanks to the advantages offered by the MUTs system built underground and which enabled the deployment of the necessary medical gas supply networks.

2. The IFEMA trade fair centre

Founded in 1980, IFEMA (Institución Ferial de Madrid / Fair Institution of Madrid) is a public–private consortium formed by the regional administration Community of Madrid (31%), the Madrid City Council (31%), the Chamber of Commerce and Industry (31%) and the Montemadrid Foundation (7%). It is an entity charged with the organisation of fairs, halls and congresses in their facilities in Madrid.

IFEMA was the 2019’s organizer of fairs and congresses in Spain, and was fifth place position on the global ranking of cities for meetings compiled by the International Congress and Convention Association, only behind Paris, Lisbon, Berlin and Barcelona (ICCA, 2020). In 2019, 898 events were held at IFEMA (123 trade fairs and congresses with exhibition, 26 festivals, concerts and long-term events, and 749 professional and leisure events), with the participation of more than 33,000 companies and 4,3 million visitors (IFEMA, 2020).

In 1991 the current IFEMA Trade Fair and Exhibition Centre was inaugurated in a developing urban area of Madrid named Campo de las Naciones (Field of Nations) and located northwest of the city near the Adolfo-Suárez International Airport (Fig. 1). It occupied a total surface of 210,000 m², of which 100,000 m² were covered and distributed in 8 exhibition halls and a reception building. Over time, several pavilions were added to the complex. Currently it has 200,000 m² covered for exhibitions distributed in twelve exhibition halls, a convention centre of more than 10,000 m², as well as spaces and equipment necessary for the optimal development of the activities that take place there, such as a meeting area, auditorium for 600 attendees, numerous restaurants and 14,000 parking spaces. It has about 400 workers.

2.1. The architectural project of the exhibition centre

In 1985, a project competition was held to choose the team that would be responsible for the design of a new fair centre for the city of Madrid. Finally, after a difficult deliberation, the jury proposed the award of the design to two teams: The access building and two pavilions located on its flanks to the architect Francisco Javier Sáenz de Oiza [1918–2000] and another six pavilions to the architect Jerónimo Junquera [1943– ] and Estanislao Pérez-Pita [1943–1999].

The final layout (Fig. 2) of the fair complex was developed along a north–south street. At the southern end of this axis is the main building, which houses the general offices and the main access to the fair complex. This building, together with the first two pavilions, make up the main facade of the complex. The other six pavilions are arranged, facing each other, on both sides of the street that widens in its central area, forming a square. A vehicle circulation ring that embraces the complex provides service access to the pavilions, which are separated from each other by side streets. This complex is completed, in its western area, with an elongated building where they are housed: at the head of it, the central heating plant and, arranged below, the premises for workshops and warehouses that a fair complex of these characteristics requires.

In the subsoil, buried under the buildings and the outside public spaces, an extensive network of MUTs was built to service the entire exhibition complex. The architect Francisco Javier Sáenz de Oiza was the inspirer of this idea. This professor of “Health and Hygiene” at the Higher Technical School of Architecture of Madrid said that “a building is similar to the human body (Saenz de Oiza, 1952), that it has a bone structure to support itself, a series of organs that must function and also a skin to make it beautiful” (Fig. 3). The architects Junquera and Pérez-Pita compared the network of MUTs with the circulatory system of the human body, made up of arteries, veins, and small capillaries to carry “the blood” to the exhibition halls.

Thinking on the flexibility and adaptability of the exhibition centre, the main idea was not to encapsulate, or strongly interconnect short lifetime building systems or components with those having longer lifetime.

2.2. The IFEMA MUTs system

The main axis of the MUT system is buried under the central street that organises the layout of the trade fair complex (Fig. 4). With a shape similar to a fish bone, new tunnels start from this connecting it to each of the exhibition halls, thus optimizing the distribution of the supply networks within each one of them. These tunnels cross each pavilion from side to side and from its upper face, technical concrete channels are...
born, every six metres to both sides, for the distribution of cables and conduits of the supply networks necessary to service the exhibition stands, which are assembled every fair or event (Fig. 5).

The MUTs system is completed with two MUTs, perpendicular to the main MUT (central axis), equipped with ramps at their ends, which communicate with the exterior level, to allow access by delivery vehicles with materials and equipment for the fairs. On one side of these two MUTs, rooms with service areas (toilets and changing rooms), installation and racks rooms, maintenance workshops and warehouses are built.

Some auxiliary MUT sections were also built connecting the MUTs of each exhibition hall approximately at its intermediate point. Its main objectives were to improve evacuation conditions in case of an emergency and to minimize the distances of the usual routes of workers who carry out network deployment or maintenance tasks inside the MUTs.

Until now, this system of tunnels and technical channels was mainly
used for the deployment of electricity, telecommunications, compressed air, water supply or sanitation networks.

The main MUT and the branches to each of the exhibition halls have an internal dimension of 250x360cm (width × height), and the auxiliary MUTs that connect approximately in the middle of the central MUT of each exhibition hall have an interior dimension of 180x360cm (width × height).

In total there are 3,135 m of MUT length built in reinforced concrete. At the ends of these MUTs, emergency exits were built through stairs that end at the level of the outer surface, and these ends of the MUTs were also used to build some underground service areas with toilets and changing rooms for workers or facility rooms.

From both sides of the underground MUT in each exhibition hall a system of technical concrete channels emerges, connecting every six metres at ground level the MUT with the lateral limits of the pavilion. These channels (Fig. 6) have an internal dimension of 40x50cm and are equipped with a continuous cover with galvanised steel lids that is located at the same level as the pavement of the pavilion. It is a system
that is very easy to install at the time of construction of the building and that allows easy accessibility for maintenance and continuous modifications required by supply networks in a large exhibition space.

In order to provide the exhibition halls with great versatility, a distance of 600 cm between the axis of these channels was estimated as optimal. This distance, adopted as a basic module, is ideal for facilitating the installation of any type of exhibition module since it allows many subdivisions into equal elements. It is a multiple of measures generally used in the construction field such as 15, 20, 30, 40, 50, 60, 100 or 120 cm. Currently, in the trade fair centre there are more than 21 km of technical concrete channels for the deployment of cables and pipes.

3. From trade fair centre to field hospital

The saturation of the health system in the capital of Spain, motivated by the COVID-19 pandemic, forced the Community of Madrid to improvise an emergency centre in the IFEMA Trade Fair Centre that should be operational in the shortest possible time. On March 20, 2020, the construction of a field hospital with a maximum capacity of 5000 conventional beds and another 500 ICU (Intensive Care Unit) beds was announced. The administration of the Community of Madrid, the Ministry of Health and the Spanish Military Emergency Unit (UME) would take on this challenge to building the largest hospital in Spain (Comunidad de Madrid, 2020a).

The project was designed to develop in several phases as new beds were needed to hospitalize coronavirus severe patients. Finally, it was only necessary to carry out a first phase, in which Exhibition Halls 7 and 9 of the trade fair centre were adapted to accommodate 1,250 conventional beds and 96 ICU beds for severe patients, Exhibition Hall 5 for acute patients, Exhibition Hall 14 for homeless people, and Exhibition Hall 10 to be a warehouse. The rest of the exhibition halls remained in reserve and they would have been adapted if the number of severely ill patients had increased.

The coronavirus COVID-19 attacks, among others, the respiratory system. For this reason, the field hospital (Exhibition Halls 7 and 9) had to be equipped with all the necessary means that might be required in a traditional hospital. In other words, these patients required basic or advanced respiratory support, so they had to have equipment capable of supplying all the medical gases to them, as well as devices to monitor their heart rate and oxygen saturation. Likewise, ICUs were essential and an adequate distance between beds had to be maintained. And also, it was necessary to add the usual logistical part that a hospital implies, such as distribution of medication and nursing material to carry out the necessary cures. On the other hand, the Exhibition Halls 5 and 14 did not need a special adaptation, simply the installation of beds.

The IFEMA exhibition halls were chosen for this project mainly for two reasons: The first, due to their large size, approximately 300 m long and between 90 and 120 m wide; and the second, and most important, due to the underground MUTs system that would allow the deployment of the necessary hospital utility networks in record time. The most important networks were made up of ducts for the supply of medical gases (oxygen, medical air and medical vacuum). In addition, other services were necessary, such as new electric lines for the connection of the devices associated with each of the beds; secure WiFi access to the Madrid Digital hospital platform for access to medical records, so that doctors work as in a permanent hospital; or provision of hospital services such as CTs or radiology mounted on site (Fig. 7).

On Monday, March 23, the MUT buried under Exhibition Hall 9 did not have any special pipes or conduits installation, beyond those traditionally used by the different fairs. In a matter of just 48 h, a large group of volunteers, many of them unemployed, coordinated by fire department engineers, were able to deploy the networks necessary to serve 814 beds (64 ICUs).

It was a pipeline deployment for three different distribution networks (oxygen, medical air and medical vacuum) along 300 m of the pavilion MUT, which had to have T-shaped connections every 6 m along the technical channels of concrete located on the pavement of the pavilion. The ducts deployed inside these channels reached a length of approximately 60 m on each side of the MUT in the Exhibition Hall 9 and 45 m on each side in the Exhibition Hall 7. In total, more than 20,000 m of essential pipes for the operation of the hospital along 510 m of MUTs and 6,300 m of technical channels. The installation of liquid oxygen deposits and distribution pipes under the two pavilions was a vital job in providing respiratory assistance to all those affected by the virus.

The breadth of the MUTs system allowed more than 30 plumbers to work simultaneously deploying and welding pipe without disturbing each other. While these workers carried out their tasks inside the MUTs, others were responsible for works inside the exhibition hall such as unrolling a sheet of PVC flooring and assembling the vertical panels to form the hospitalisation modules, with their corresponding medical gas outlets, beds for patients and other necessary equipment.

4. A modular hospital

To optimise the management of the IFEMA field hospital, hospitalisation modules were designed in such a way that they could be managed by independent teams of health personnel. Each of the modules was the closest thing to a nursing control in a traditional hospital, designed with the main objective of facilitating the work of professionals. Each of the conventional modules had 50 beds, a nursing work area, pharmacy, clean changing room (to put on protective suits), dirty changing room (to take off protective suits), a cleaning-room, a warehouse, and areas for working and monitoring patients (Fig. 8).

The fact that all the hospitalisation modules were identical optimised both the construction of the field hospital and the work of the health workers. On the one hand, the chosen module solution facilitated the rapid construction of the field hospital, its expansion if necessary and gradual start-up as the modules were completed. On the other hand, it also facilitated the work of doctors and nurses, who could be assigned to work in different modules (even in another exhibition hall), always

![Fig. 7. Interior space of an exhibition hall: before the adaptation works (left) and once the hospitalization modules have been assembled (right).](image-url)
being familiar with the working environment and knowing, at all times, where to find the material they need to do their job.

In the Exhibition Hall 9, 15 modules with 50 conventional hospitalisation beds each (750 beds) and 4 ICU (Intensive Care Unit) modules with 16 beds each (64 ICU beds), were built (Comunidad de Madrid, 2020b). In the Exhibition Hall 7, were creates 10 modules with 50 conventional hospital beds each (500 beds) and 2 ICU modules with 16 beds each (32 ICU beds). (Fig. 9).

In addition to patient care, a laboratory for clinical analysis was operating at the Madrid Trade Fair Centre, and it also had the laboratories of external hospitals located in nearby areas to carry out more complex clinical analysis. This field hospital was also equipped with radiology devices, mainly portable, for the radiological control of patients, as well as first-aid kits and pharmacy stock management.

In the event that the situation had reached overflow, and the number of patients to be hospitalised had increased, the plan envisaged the replication of this modular hospital model in Exhibition Halls 1, 3 and 5 to expand the healthcare spaces and increase the number of beds to 3,000 in a first scenario (Exhibition Halls 1 and 3), and, if the situation requires it, to reach 5,500 in total.

The modules were designed based on the configuration of the existing technical channels on the floor of the exhibition halls. Therefore, the distribution of beds was adapted to an inter-axis separation of 6 m in order to have a supply of medicinal gases at all times. Each standard module has dimensions of 30x21m and, within this module, each two facing beds occupied a rectangular floor space of dimensions 6x3m.

After having cared for nearly 3,812 patients, alleviating the overload of Madrid hospitals, and avoiding their collapse, the IFEMA field hospital had fulfilled its mission and closed its doors on May 1. However, the closure did not imply the total dismantling, since the entire infrastructure of medical gases supply has been left intact in case a resurgence of the pandemic makes it necessary to open it again.

5. Conclusions

The quality of life in cities increases when they have large buildings with great adaptability, which undoubtedly contributes to making cities more sustainable and resilient. Buildings are usually designed with long-
Investigation, Visualization, Writing - original draft, Writing - review

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be taken into account from the first phase of the project. The construction of MUTs under the exhibition halls, combined with a system of technical channels for cables and pipes, is an ideal solution to provide functional adaptation to this type of building. The MUTs allow, in an agile and simple way, the maintenance and renewal of existing utility networks and, of course, the deployment of new ones in the face of unforeseen needs.

The correct dimensioning of the MUTs makes it possible to expand the buildings, such as the IFEMA fair trade centre in Madrid, which was expanded by constructing four new exhibition halls. Existing MUTs were used to enable utility supplies to these buildings. In addition, the use of a MUTs system is an optimal solution when the heat or cold production is centralised in places other than buildings where consumption points are located.

With this case study, as a consequence of the COVID-19 pandemic, it is demonstrated how a correct design of buildings (or complexes made up of several buildings), focusing on their adaptability and their long-term use, allows to face to an increasingly uncertain, complex and changing future. And also, as it has been verified in this article, the correct planning and use of the underground space contributes to this.

MUTs are a smart solution designed for quick adaptation and sustainable development of an exhibition centre or any large facility, as they allow the deployment and hosting of supply networks not initially foreseen. Cities that have this kind of infrastructure are more resilient, prepared to face any unforeseen situation, and therefore and therefore they are sustainable and high quality of life cities.

As a learning from this pandemic, and in anticipation of future ones, it would be interesting for all cities to do a study on which buildings have the capacity to adapt in case of emergency and the resources that should be allocated to it.

It would also be interesting that, in the future, when cities are going to build large buildings to host large fairs, exhibitions or events, they will be provided with the constructive solutions and the necessary resources so that in the event of an emergency can be easily adapted as a field hospital. As explained in this article, in the case of IFEMA-Madrid the MUTs system was the main enabler for the success of the field hospital.

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Tunnelling and Underground Space Technology incorporating Trenchless Technology Research 113 (2021) 103951

CRediT authorship contribution statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.
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