

Use of the CPTED Methodology (Crime Prevention through Environmental Design) and Fire Protection Principles in the Design of the New Form of Gas Stations and Their Surroundings

PETRA DOSTÁLOVÁ, GABRIELA KRÁLÍČKOVÁ

Faculty of Applied Informatics,
University of Tomas Bata in Zlin,
Nad Stranemi 4511, Zlin,
CZECH REPUBLIC

Abstract:- Gas stations are an integral part of public space. However, they are not only a place of buying and selling but, unfortunately, also a place with significant risks, which include robberies and, at the same time, the possibility of fires and explosions. The article is focused on safety at gas stations and a theoretical presentation of the CPTED methodology. Together with the principles of fire protection, they should contribute to the level of a safe environment. The work proposes introducing and observing measures to increase gas station safety.

Key-Words:- CPTED methodology, Alarm Systems, Camera Systems, Gas Station, Terex

Received: June 16, 2022. Revised: October 29, 2022. Accepted: November 30, 2022. Published: December 28, 2022.

1 Introduction

Today, which is modern and rapidly developing, most of us cannot imagine life without cars. The use of vehicles is related to the necessary use of gas stations. There are very few gas stations that do not use electronic security. Operators are aware of the risks associated with the operation of gas stations. In addition to the risks associated with the flammability of the sold fuels and other products, they also include dealing with higher sales and often continuous operation.

At the same time, it is necessary to think about the financial efficiency of security systems. Each station has specific security measures that reflect its location, the average number of customers, their composition, and the risks associated with criminal activity. Even if there are established procedures that must be followed, it is necessary to keep in mind the safety risks associated with the over-pumping of fuel.

2 Safety of Gas Stations

A gas station is a semi-enclosed space that is separated from the road. It is also a commercial area where customers can purchase various products. Ensuring the safe operation of gas stations ranks among the primary priorities of operators.

Local and specific factors include important aspects in assessing the possibility of criminal activity at a gas station in a given location. They

contain information about crime in a given area or the nearest neighborhood, which can be used with security forces to map and determine the density of criminal activity. The specific location of the gas station and the social risks arising from the surrounding demographic environment should already be assessed when designing the gas station. The consequences of a whole range of factors directly affect the safety of the gas station.

Potential perpetrators can mainly be:

- Thieves
- Armed robbers
- Organized gangs
- Counterfeiters
- Vandals
- Arsonists.

2.1 Types of Crime at Gas Stations

The occurrence of crimes at gas stations also depends on the time of day. Armed robbery, theft, and use of counterfeit currency may occur during opening hours. Looting or arson often occurs during the closing (night) hours. Armed robberies tend to target a gas station cash register, sometimes, but less frequently, a safe. Usually, the cashier is attacked. These crimes are also aimed at transferring sales to the bank. Offenders mainly target gas stations with poorly protected cashiers. A burglary occurs especially when the objects are abandoned. They

tend to focus on goods in the store, warehouse, and safety. A suitable building structure and its resistance affect the failure of a break-in.

Goods on display in the store are particularly vulnerable, as they may be subject to further criminal activity or theft. Anonymity and easy escape of customers are attractive conditions for criminals. It is, therefore, necessary to pay special attention to the placement, display, and fixing of goods in the store.

The tempting and most common crime is failure to pay after filling up fuel or oil lubricants.

Because cash payments are made at gas stations, this option is abused by experienced counterfeiters. Although this criminal activity is not very common, criminals use counterfeit banknotes and checkbooks and abuse payment cards and payment systems. ATMs for cash withdrawals are often located near gas stations, where there are generally attempts to obtain confidential data about payment cards. These include owner names, card numbers, and security codes.

There is a dynamic movement of people at gas stations. Customers do not stay on the premises for a long time, but even so, the police register attempts to steal vehicles, theft of goods, and the vehicles themselves. At the same time, the space is misused for the sale of drugs or offers of prostitution, and this is also related to the damage and destruction of parts of the building accessible to all customers of the gas station.

Due to the presence of flammable and explosive substances, gas stations are sensitive to the risk of arson.

3 CPTED Methodology

CPTED = this is a set of security principles that are used in the fight against crime and violent attacks. CPTED is based on the theory that crime can be affected by proper design and effective use of the built environment. How commercial and public buildings are designed and built can significantly impact the crime rate committed in specific locations. With the proper application of CPTED principles, facilities can be made more secure and less prone to criminal activity and violent attacks.

CPTED is based on four primary strategies (they can be applied to new construction, as well as to historic centers or older buildings).

3.1 Natural Supervision

The entire space must be clear so that there is good visibility and recognition of possible perpetrators of

criminal activity. Maintaining well-arranged and well-lit spaces, which have a good view from the outside and the inside of the objects, are suitable solutions. In the given area, modifications and installation of suitable elements to make hiding impossible have been carried out. An important role is played by camera systems, which also have analytical functions for automatic image evaluation.

3.2 Natural Access Control

It significantly reduces the opportunity for criminal activity and violent attacks. The goal is to make direct access to a potential target more difficult and escape routes more difficult for the perpetrators. The principle of natural control is distinguished between the public and private sectors. This includes a few elements - entrances and exits, gates, turnstiles, fencing, natural barriers, lighting, and others, to direct the movement of people within the building. Mechanical and electronic security systems are used for access control. Access control has, as a part, deployed control technology in a visible place - for example, detection frames and security scanners. On the contrary, for example, X-ray equipment can be placed hidden. The information system is an integral part of this strategy, which informs users about access routes.

3.3 Territorial Strengthening

This strategy promotes social control based on the self-interest of the users of the space (a sense of ownership belonging to the territory). Visitors, tenants, employers, etc., i.e., invited persons, are themselves interested in access control. A sense of "home rule" and "ownership" is encouraged in the device users; all suspicious persons are more identifiable in such an environment. Part of this strategy is also time zoning - when and at what time and what activities usually take place in the given territories. Another essential part is the so-called routing, i.e., connecting and accessing routes for users of individual functional areas (from where to where). Continuous maintenance of all territories and systems is essential. The environment level guides visitors to the desired behavior and "educates" its users.

3.4 Casing Protection

This is about building security to such a level that it is difficult to enter the building's premises forcibly. This includes locking systems, mechanical and electronic elements of security systems, protective window films, and correct secure fastening of doors and windows. The purpose is durable security

preventing the penetration of attackers and criminals.

4 Gas Station Security Strategy

Crime prevention strategies:

- Working conditions,
- Opening hours,
- Contact between the manager and suppliers, employees,
- Geographical and social environment,
- Level of crime,
- The opinions of the staff on the work in the given place, [13].

All technical and personnel measures designed to fight crime should be analyzed using these levels:

- Deterrence (discourages attack),
- Denial (attack blocking),
- Delay (slows down the attack),
- Alarm (devices and procedures to alert the security forces about an attack).

A security plan should be compiled from the results of this analysis. The safety plan should include all safety measures, and all employees should be familiar with them.

A security strategy implies the following choices:

- the location of the gas station,
- internal organization (space, building),
- device protection,
- human leadership.

5 Gas Station Security Design

It is possible to deal with the security proposal during the new gas station project itself, or it is possible to secure the existing state newly and thus invest in increasing security, [9].

5.1 Walls, Facade, and Roof

Materials resistant to manual attack should be used. If the building structure is light, it is possible to increase safety by lining it with welded steel mesh, etc, [1].

The front surfaces should be smooth, as protrusions, slats, etc., can be helpful for illegal entry into the building.

5.2 Public access

- enabling remote locking of typically freely open doors in the event of a problem,
- unlocking entrance doors at gas stations open at night,
- doors equipped with a detection system to protect against theft of goods.

5.3 Cash Desk

The design of the checkout counter should prevent the following:

- so that the customer can see the contents of the cash drawer and be able to seize the payment,
- so that the customer can skip the checkout counter,
- for the customer to physically attack the cashier.

At night, when the cash register is closed, payment is made through an opaque or reinforced glass cash counter equipped with a secure filing device and an intercom.

The signage should inform the public that the gas station manager does not have keys to the safe, which is protected by a time lock.

The cash desk should be equipped with an emergency button or pedal directly connected to the monitoring center. It should also be under constant surveillance by the camera system.

A good view of the dispensers from the shop building is also recommended, which can be achieved with elevated stands.

5.4 Store

The protection of this space needs particular attention, as property crime can develop here.

Protective elements can be installed on the sale premises - for example, a camera system, clear shelves, mirrors, etc., [1].

Emergency exit doors are controlled by a lever handle or button (meeting the conditions of EN 179) and controlled by a horizontal handle (meeting the conditions of EN 1125).

The toilet area must be secured against the sale and use of drugs. Design toilets in such a way that there is no possibility of hiding anything, use access control devices, and discourage people from illegal activity by frequent cleaning service visits.

The manager's office is located, so its access is hidden from the public. It is a space for the manager and staff to work in peace and deal with sales, distribution, and access to information about the gas station's management (alarm systems, camera systems, technical systems). This room should have a door equipped with an automatic closure and

permanently locked with an electromagnetic lock or a video camera to identify people.

The warehouse should be specially reinforced. Doors to the warehouse should be puncture resistant. Security with an anti-intrusion system, which is connected to the alarm system and also to the camera.

The safe should be anchored in concrete and equipped with a time lock. It is advisable to place free-standing safes against the inner wall of a solid structure. Lock combinations and key cards to access the safe must be strictly supervised. An alarm system should secure the area where the safe is located.

Internal retracting metal blinds during the closing time are used to strengthen the protection of premises that are considered sensitive. They can cover exposed expensive goods, alcoholic beverages, and tobacco products.

Preventing darkness is the task of emergency lighting. It is essential to constantly maintain sufficient **lighting** throughout the building in bad weather or at night. It enables the combination of natural surveillance and prevention, [12].

5.5 Camera Systems

Design solutions per:

- the current or planned lighting system, the quality of lighting to support the operation of the camera system,
- the space and the activities carried out in it, which are to be monitored,
- regular maintenance of cameras and elements of camera systems, control of image quality,
- by placing them in anti-vandalism shelters in places with a high crime rate,
- handling the record - time and date of creation, etc.

The alarm detection system is used for the automatic detection of intrusion through the opening, the building shell, and the detection of the movement of people in the building; this will improve physical security measures. The control panel of the alarm system must not be easily accessible. The alarm transmission system must be protected or redundant. The alarm event is to be processed in real-time. Response to an alarm event should be carried out in the shortest possible time.

5.6 A Centralized Protection Desk

It is a service offered by private companies. This company has built its dispatching station, which constantly guards objects secured employing electronic security signaling (PZTS) or electronic fire signaling (EPS), which are connected to the counter. All the information the given alarm system

can provide can be transferred to this desk. With PCO service, the gas station is connected to private security agencies. When the staff leaves, they lock the facility with a code to secure it. If someone breaks into it, a siren is triggered, a siren is sent, or a signal is picked up by the central protection desk located in the agency. The agency will immediately send an intervention unit to the scene. At the same time, he calls the client on the agreed telephone numbers and informs him about the trip.

5.7 Vehicle Entry and Exit System

These systems can provide information about vehicles, or at a company gas station, information about drivers, etc. The system can include vehicles divided according to working hours and the possibility of refueling vehicles or preventing the refueling of foreign vehicles, private vehicles, etc. Everything can be set according to the client's requirements. The system divides, once set, the vehicles into predetermined categories. In the security field, this system simplifies the work of security staff, as the error rate of employees is reduced. This system also monitors behavior outside the established norms. From the point of view of traffic safety, the system can detect a traffic violation, when it can be, for example, the speed of vehicles in the gas station area and others. The subsequent connection of the system with third parties (police and firefighters) is effortless. The system works based on a web interface; therefore, it is possible to use it from anywhere.

6 Principles of Fire Protection of Gas Stations

The conditions for the sale of fuel are determined by legal regulations and relevant building, technical, hygienic, and fire standards. As part of the operation, there is the sale and prior storage of fuel, lubricating oils, and other chemicals. Antifreeze liquids for coolers and windshield washers, brake fluids, motor oils, and cleaning agents are sold in the sales premises of gas stations. All the listed products contain dangerous, variously flammable chemical substances and are thus a source of danger to the environment, health, and lives. For these reasons, modern gas stations are designed and implemented with maximum operational safety and environmental protection, [6].

Adverse effects and dangerous situations occur mainly during transport and transportation, handling, discharge, storage, and storage. Customers themselves are also at risk during refueling.

Emphasis must always be placed on the prevention and elimination of possible accidents and extraordinary events so that situations are prevented to prevent their recurrence, [7].

Essential fuels include gasoline, diesel, biodiesel, and gaseous fuels. For their underground storage, only double-walled steel tanks are used. Tanks are usually placed on a concrete slab and sand bed, which prevents mechanical damage. In the case of several tanks or special cages to protect gas tanks, it is necessary to observe the specified mandatory distances, [8].

At each gas station, employees must be trained in crises and know the procedures for fuel spills, accidents, equipment malfunctions, and fires. All employees must be equipped with personal protective equipment and first aid equipment. Individual procedures and the emergency plan must be regularly revised. As part of the safety standards, it is stipulated that a telephone line must be available at each gas station, and a list of emergency lines must be visibly located. The station operator must have a main emergency switch available to stop the power supply to the refueling units. This switch should be easily accessible and tested regularly. It is also necessary to pay attention to the correct location of safety data sheets for individual stored substances. Stocks of fuel must be registered and correctly divided according to flammability, [11].

Sources of fire:

- hot or burning body, open fire
- thermal manifestations of chemical reactions - friction
- sparks
- static, atmospheric electricity
- inappropriate electrical installation

Avoidance options:

- proper organization of work and compliance with procedures
- equipping the premises with the required number of fire extinguishers
- use of suitable personal protective work equipment
- use of non-sparking materials and tools
- removal and appropriate operator response
- checks of the concentration of hazardous substances during the work of employees by a person from an external, ventilated environment.

7 Modeling the Emergency of an Explosion at a Gas Station

In the next part, we chose to model an emergency with the help of a particular Terex program, during which an explosion occurs at a gas station.

Based on fire statistics, possible and predicted situations, activities, and phenomena, the following list of possible causes of fire or explosions on the gas station premises can be given. These assumed situations were modeled using the TEREX system, [10].

The researched gas station is located on the outskirts of the city. It was put into operation in 2008. The owner of the gas station does not want its name to be published, [14].

The filling station is intended to dispense diesel and automotive gasoline for promoter road vehicles. One four-chamber underground tank of 50 m³ is located at the station for fuel storage, connected to three self-service dispensers, under a canopy, and in an isolated dispensing area, [15].

The following image documents the location of the investigated gas station.

We model the emergency under conditions where the tank is almost filled to determine the maximum possible consequences. When calculating the volume of fuel liquids in underground tanks, I considered tanks with a total size of 45 m³ + a tank for power drips, which has a volume of 5 m³.

Tank capacity and division by product (=highest quantity stored at the filling station):

- Diesel 20m³
- BA Natural 98 7m³
- BA Natural 95 18m³
- Drips 5m³

The following was found using this program. In the event of an explosion at this gas station when the tanks are almost filled, it is necessary to evacuate the population to a distance of 490m. In the event of an explosion, the reach of the cloud would be 100m. Mortality is determined to be 10% within a radius of 260m and 50% within a radius of 220m.

Persons who would be in the third zone and above are at risk of 1st-degree burns, including those who are located almost half a kilometer from the given object.

Cigarette, carelessness

The glow temperature of a freely smoldering cigarette reaches values in the range of

350°C–480°C, up to a maximum of 770°C. This temperature is sufficient to ignite flammable vapors escaping from fuel injection.

An electric arc, short circuit

An electric arc is an accompanying phenomenon of an electric short circuit. It occurs where an electrical circuit is interrupted, through which a strong electric current flow, or where there is a high voltage at the tripping point. It reaches high temperatures ranging from 3000°C to 10000°C.

Atmospheric electricity

The lightning discharge has a current of up to 80000 A, and its effect is concentrated in a brief moment (lightning lasts 10^{-6} to 10^{-5} s) and can be compared to the effects of an explosion. Lightning can destroy an entire building; its effect is enough to kill a person and ignite flammable materials.

Welding, grinding, cutting

During flame welding, the heat produced by the combustion of flammable gas in a flow of oxygen is used. Acetylene is a flammable gas. Temperatures of 2700°C to 3200°C are reached here. During electric arc welding, temperatures of approximately 3000°C (flowing metal drops) are reached.

Electrostatic charge

It can occur when connecting and disconnecting the filling hose of the car when filling and filling fuel, mainly when the fuel flow rate in the pipeline needs to be observed. If the field intensity exceeds the breakdown value of air 30kV/cm or other gas, the spark charge will jump.

Hot engine surfaces

Hot surfaces and engine surfaces when the bottled fuel product comes into contact with parts of the engine, especially the exhaust pipe, engine block, etc., or fuel leakage when the vehicle engine is not switched off.

Fire transmission

Transmission from an accident to the nearby road is unlikely to occur in the area of the gas stations; it is possible from a fuel pick-up station, from pumping fuel due to customer carelessness (e.g., smoking), and from food areas in dry weather from dropped cigarettes.

Electrical installation

Inadequate coverage of the electrical installation determined according to the relevant documentation, in case of changes in the type of environment,

unremedied defects of the electrical equipment revision (e.g., sparking).

Gross negligence

Lack of training, ignorance, possibly mistake of the service station operator when operating and operating the equipment, underestimation of the fire risk, failure to remove a defect in the technical equipment of the service station, possibly not immediately removing the damaged technological equipment from the operation, failure to follow instructions and manuals for electrical appliances, throwing cigarette butts into containers in the room of the service station operator combustible materials.

When modelling an emergency in the Terex program, no risks were noted for which the selected gas station did not have prepared documentation. The analysis at the gas station showed that all regulations are followed, and all risks are approached responsibly.

All regular checks and revisions are recorded in the operating logbook and book of the gas station.

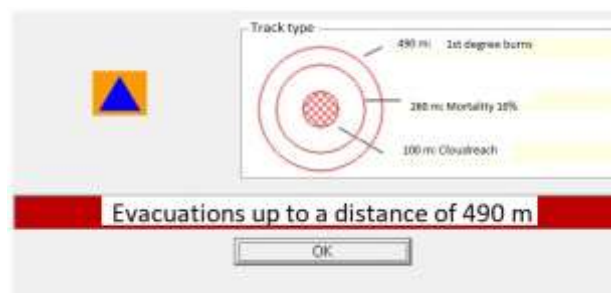


Fig. 1: Evacuations distance (own processing)

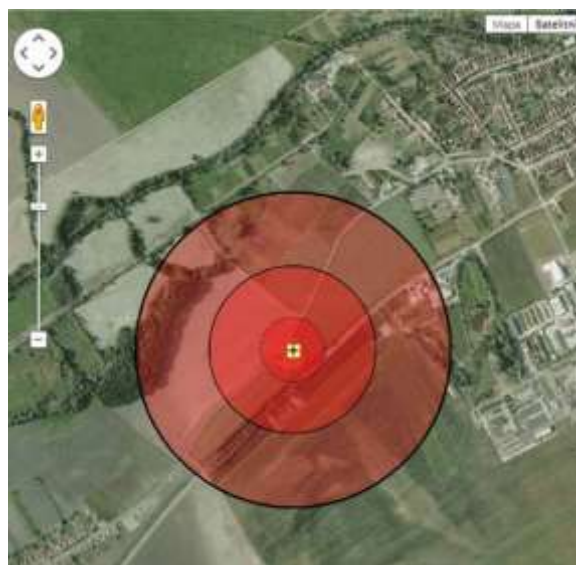


Fig. 2: Map of the selected gas station - danger zone (own processing)

It is essential to have correctly compiled explosion protection documentation. The documentation on explosion protection comprehensively assesses the risks to the safety and health of employees and determines protective measures.

Documentation on explosion protection must include the following:

- description of workplaces and workspaces due to the danger of explosion,
- description of technological procedures or activities,
- description of substances used, safety parameters,
- results of risk analysis,
- measures were taken against explosions,
- introduction of protective measures against explosion practice,
- coordination of explosion protection measures,
- appendices to the explosion protection document.

8 Conclusion

This article focused on safety at gas stations. The first part of this article was a general specification of gas station security with a definition of possible types of criminal activity. The next part focused on the theoretical presentation of the CPTED methodology, which defines the individual strategic steps of crime prevention in the selected object. Fire protection and its principles, described in the following section, are also related to the safety of gas stations. This article's ultimate goal is to design an application to increase security at gas stations.

In all parts of the article, individual steps were presented that, after implementation, help prevent crime at gas stations and whose observance contributes to fire safety. One of the essential basic measures can be considered the manual security of the gas station, which will prevent criminals from entering the protected object. This part focuses on the equipment locations and security measures proposed for the proper operation of the business and the reduction of possible threats to customers and the gas station staff. One of the most important measures is installing camera systems, including a recording device and a connection to the cloud.

In the field of fire protection, it is necessary to comply with legal procedures and obligations. By meeting all these conditions, the risk associated with dangerous criminal behavior and fire risks can be reduced so that both the customer and the service station staff feel safer.

When operating gas stations, it is always necessary to compare the primary purpose, i.e.,

creating profits and other added values for the operator, with ensuring high standards of safety when operating the gas station, especially concerning the protection of customers. An imbalance in these two parameters often has severe consequences for both parties.

Acknowledgments:

This work was supported by the Internal Grant Agency of Tomas Bata University under project No. IGA/FAI/2022/005.

References:

- [1] ČSN P CEN/TR 14383-5 Prevence kriminality- Plánování městské výstavby a navrhování budov, Část 5: Čerpací stanice: 2011. [online]. [cit. 21. 08. 2022]
- [2] Fáberová V., *Prevence kriminality prostřednictvím enviromentálního designu – CPTED*. [online]. [cit. 18. 08. 2022], Dostupné z: <https://doverville.cz/novy-pristup-k-reseni-bezpecnosti-a-ochrany-mekkych-cilu-verejnych-a-komerčních-budov-cpted/>
- [3] Petrol.cz, *Bezpečnost na čerpací stanicích*, [online]. [cit. 21. 08. 2022], Dostupné z: <https://www.petrol.cz/media/167436/pm191in-teraktiv.pdf>
- [4] Černý R., *Bezpečné chování řidičů u čerpacích stanic*. [online]. [cit. 21. 08. 2022], Dostupné z: <https://adoc.pub/bezpenec-hovani-idiu-u-erpacich-stanic.html>
- [5] Czech Republic. Zákon č. 311/2006 Sb., o pohonných hmotách a čerpacích stanicích pohonných hmot a o změně některých souvisejících zákonů. [cit. 22. 11. 2022], Dostupné z: <https://www.zakonyprolidi.cz/cs/2006-311>
- [6] Hanh, H. Nga, L. Huy, D. Lan, L. and Dat, P. The Quantified Analysis of Causes of Market Risk Fluctuations in the Group of Construction, WSEAS Transactions on Environment and Development, 2020, vol. 16, pp. 189-197.
- [7] ČSN 73 6060. Čerpací stanice pohonných hmot. Praha: Úřad pro technickou normalizaci, 2018.
- [8] ČSN 65 0201. Hořlavé kapaliny - Prostory pro výrobu, skladování a manipulaci. Praha: Úřad pro technickou normalizaci, 2018.
- [9] Krizová připravenost firmy. Praha: Wolters Kluwer ČR, 2014. ISBN 978-80-7357-983-8

- [10] Zákon č.240/2000 Sb. Zákon pro lidi [online]. [cit. 2022-11-20]. Dostupné z: <https://www.zakonyprolidi.cz/cs/2000-240>
- [11] Čerpací stanice [online]. [cit. 2022-11-20]. Dostupné z: <https://www.cerpaci-stanice.eu/>
- [12] MIKŠOVSKÝ, Tomáš. Čerpací stanice: Návrat do historie tankování [online]. 2012 [cit. 2014-03-11]. Dostupné z: [http://www.petrol.cz/aktuality/archiv/2012/29/navrat-](http://www.petrol.cz/aktuality/archiv/2012/29/navrat-29/navrat-)
- [13] ANTUŠÁK, Emil. Krizový management: Hrozby -krize -příležitosti. Praha: Wolters Kluwer ČR, a.s., 2009. ISBN 978-80-7357-488-8.
- [14] Barta, J., Ludík T. TerEX-modelování a simulace. 2012. [online]. [cit. 21-11-2022]. Dostupné z: https://moodle.unob.cz/pluginfile.php/26278/mod_resource/content/1/Studijni_pomucka_TerEx.pdf
- [15] HERETÍK, J., BARTA, J., BUMBOVÁ, K. 2008. Simulátor pro výcvik a přípravu krizového/nouzového managementu. In 5. mezinárodní konference "Crisis Management": sborník abstraktů a elektronické verze příspěvků na CD-ROMu [CDROM]. Brno: Univerzita obrany, 2008. ISBN 978-80-7231-510-9.

Creative Commons Attribution License 4.0 (Attribution 4.0 International, CC BY 4.0)

This article is published under the terms of the Creative Commons Attribution License 4.0

https://creativecommons.org/licenses/by/4.0/deed.en_US