Location of emergency access points in rail tunnel: a proposal for New Centre Project in the city of Maringá-PR-Brazil

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Abstract: The city of Maringá - PR has started a process of changes in its central area, in order to improve the flow of vehicles. Thus, it was designed and deployed a railway tunnel in this central area to improve the conditions of vehicular traffic at the place called in English as New Centre Project. However, on the finished project, the security mechanisms for the tunnel and its surroundings area were not considered, putting at risk the lives of people who live, work or just circulate around it. Given these factors, the present work aims to propose the location points of emergency access of the rail tunnel to enable favourable conditions in critical situations. As methodology it was modelled as a Set Covering Problem (SPC) and, in its implementation, a graph with possible candidate points was designed, as well as some relevant factors such as population density, tunnel warming’s degree, traffic generator poles and local difficulty access. It was simulated some situation varying critical distances to verify the coverage between evaluated points. It was suggested, as the best option, to add two new access points with a critical distance of 800 meters.

Keywords: emergency access; rail tunnel; Set Covering Problem (SPC)

1. INTRODUCTION

When analyzing the appearance of Brazilian cities, it can be stated that these cities grew around rivers, roads and railways. In part, the maintenance of a city or region was always due to the paths it leads (Borsagli, 2010) Thus, it is through them that the migratory flows and the goods travel among other tangible and intangible factors are developed, which are necessary for the appearance, growth or decay of an urban area. Therefore, the paths are crucial to define the importance and influence of a city in a region. The urban transportation is an essential activity that covers all people and movement of goods in the cities, and along with globalization, it formed a linkage in the cities development chain, the lack of it would lead the cities into crisis.

What refers to of the city of Maringá-PR, the urbanization process occurred also focused on the geographical conditions of the region, and its milestones. The city was designed by an engineer named Jorge Macedo Vieira, requested by the Company of Improvements “North of the Paraná” (CMNP), which was responsible for the colonization of northern Paraná (Meneguetti et al., 2009). The railway’s route line, at the east-west direction, was essential to demarcate the city’s original layout and its railway station was, at the time, a symbol of regional city’s progress, and it was also responsible for the outflow of harvest from several smaller Centres.

However, despite the railroad has provided a lot of development to the city, when the city grew it become a problematic focus since it was located in the city central area, creating a barrier on the flow of vehicles for this site. Another element to be noted is that at this central area it was also installed the maneuvers switching courtyard (flammable), which occasioned risks to the population by the activities developed during the railway. Then, in order to lead improvements for this area off the city, in 1985, the city's mayor, Said Felício Ferreira (1983-1988) ordered the architect Oscar Niemeyer a project to recover and improve such space. The project was called "Agora", which proposed to lower the railway line at open sky with commercial buildings along it. The free area where the present buildings were inserted should be an “agora”, a large square that gave name to the project. However, due to economic infeasibility, the design was changed during the administration of the Mayor Ricardo Barros (1989-1992), being renamed as "New Centre Project".

The "New Centre Project" was started in 1995, by lowering the railway line, and in 1996 it was built a completion for the tunnel section between São Paulo and Paraná Avenue. In late 1999, the tunnel was completed on the stretch between São Paulo and Pedro Taques Avenue, allowing the implementation of road that was projected on a slab, and the completion of the upgrading works on the ground, which was necessary for their occupation (Meneguetti, 2001). Later, it was given continuity to the other snippets proposed in the project.

In this action to improve the city traffic flow, the security mechanisms for the tunnel and its surroundings were not designed. The project was approved and implemented, however, it presents security issues once there is no emergency exit and, in a possible accident event, it would require a long time to send an emergency team to this location. Considering the risks of an accident, Brasiliano (2005) it is notice the potential danger of an accident that was neglected by the administrators of the project, as well as the lack of previous action to confront an emergency situation could result in serious consequences.
Thus, aid programs should contemplate future factors to ensure that people are not vulnerable to eventual disasters (International Federation of Red Cross and Red Crescent Societies, 2012). The lack of immediate action in the event of an accident can result in death, fire, destruction of property and facilities. In this purpose, the present work aims to present a proposal for location of emergency points in Rail Tunnel: New Centre Project, in order to enable favorable conditions in emergency situations.

This text is organized into four sections, besides the introduction. In Section 2, it is presented the concepts related to Disaster Management, Location Problems and Set Covering Problems, which was very import for the development of this work. In section 3, it is characterized the environment in which the study case was conducted as well as the proposed location of emergency access model. The results are shown in Section 4. Finally, in Section 5, the final conclusions are made.

2. LITERATURE REVIEW
In this section the fundamental concepts are addressed to meet the objectives proposed in this paper.

2.1 Disaster Management
Disasters are defined as the result of adverse, natural or manmade events, on a vulnerable ecosystem causing human, material and environmental damage, and consequent economic and social losses (National Policy of Civil Defense, 2007).

These disasters can be classified by National Policy of Civil Defense (2007) as its primary cause of the causative agent as: natural (caused by imbalances and phenomena of nature); human or anthropogenic (caused by human actions or omissions); mixed (when the human actions and/or omissions contribute to enhancing, complicate or aggravate natural disasters).

It can be said that natural, human and mixed causes may arise in activities performed in a railroad. The natural ones can be caused according to where it is installed, soil erosion, landslides, etc.; regarding human and mixed, which lead to emergency situations, it is caused by derailments, motor vehicle (level crossing) and/or building (after derailment), employees trampling, collisions between locomotives, wagons or locomotives drops, rolling bridges, monorails and other lifting equipment, leaks at the maintenance time, load supply or movement of locomotives or wagons, poor maintenance, fire, boiler explosion (for steam locomotives), structural collapse of bridges and tunnels, structural fatigue of rails, wheels and other equipment, signaling equipment failure, human error failures, etc.

In the case of accidents involving trains or passenger loads occur in tunnels; these risks are even greater considering the lack of security in this place. And, to reduce the harm caused by these accidents, the railway companies must be prepared to act by the time it happens, with quick and logical actions that can restrict the damage caused by it. However, the city emergency service (provide by the Fire Department, Police, ambulances, etc., as fixed by the Federal Constitution of 1988, art. 144) must also be prepared to attend this situations.

Fires in tunnels are rare (Barth, 2002; Mashimo, 2002), however, when it occur, it has tragic consequences due to the vulnerability of concrete by spalling effect (water expansion until it blast the coating) and the difficult to quickly dissipate the heat and smoke (Blanco, 2012). Most European Countries and some countries around the world usually invest a lot of money in security measures and have strict regulations regarding safety in tunnels. Given these factors, in 2009, the Brazilian Association of Standards and Techniques (ABNT) published the NBR 15661, a Fire Protection in Tunnels.

The NBR 15661 aims to present requirements and criteria for prevention and protection in case of fire or other emergencies that occur in tunnels across the country, it also establishes the installation of communication networks (voice and video), control Centres, fire and gas detection systems, access control and other means. Even when it is prevented, there is a risk of occurring accidents, and it must, therefore, deal with a contingency condition (Daleprane, 2007).

A contingency is an emergency that must be addressed quickly and effectively, targeting the maximum reduction of their impacts on the environment (Petrobras, 2005). A Contingency Plan is an important tool for activities which are designed to track the disasters and emergencies, in order to help people at risk, to avoid or to recover the effects of the disaster, and it is crucial for disaster management (SCHULTZ, 2008 apud LIMA et al. 2011).

The contingency planning is a component of a much broader process of emergency preparedness, which includes items such as business practices, business continuity and disaster recovery planning. The cycle of disaster is triggered by an event and then the response to this event begins. The main goal is to respond to this event with correct specifications, so that the loss of life and property is minimized and subsequently to reconstruct the affected region in order to reduce future losses (TRB, 2012). This management can be divided into three phases: Mitigation (Preparation and Prevention), Response and Recovery (Balbi, 2008), in other words, before, during and after the emergency.
According to Souza (2012) a prompt emergency response can mean the difference between life and death. And those strategies in the recovery and reconstruction can reduce the human suffering and financial loss, providing a quick return to normal community functions. These responses involve the activation and implementation of plans and emergency procedures, as well as to coordinate efforts so the actions can be designated as, alerting, warnings; availability of adequate information to the public; assistance during and after the disaster, including care of the dead and wounded by providing emergency shelter and places for evacuation, medical care, food and clothing (Balbi, 2008).

A branch that enables quick responses for these events is the Humanitarian Logistics, that involves planning, implementing and controlling the flow and storage of materials in an efficient way and with low cost, taking goods and information from the consumption point to the source point with the purpose to alleviate the suffering of people who are vulnerable to a variety of emergencies (Villafluerte, 2010).

The emergency logistic planning is essential so materials, doctors, rescue equipment specialized, rescue teams, etc., can reach the affected areas as soon as possible to hurry the relief operations (Özdamar et al., 2004). Different theories have been developed to analyze the emergency service problems, including: location problems (Toregas et al., 1971), location-allocation heuristic (Cooper, 1963; Taillard, 1996), specific coverage areas (Church & ReVelle, 1974; Moore &ReVelle, 1982), simulation (Shih and Su, 2003), hypercube model (Oliveira & Gonçalves, 2004), among others.

2.2 Location Problems

In the decision-making process, several issues can be inserted when it seeks to find parameters direct to urban and emergency improvement services. An interesting approach to emergency systems analysis is the combination of facility location models and simulation techniques to analyze the generated solutions (Silva & Pinto, 2009). In this topic it will be addressed only definitions about location issues.

Gonçalves (2012), Larson & Odoni (2007) & Souza et al. (1996), summarize some models considered effective for location problems. These models are classified by the nature of the objective function to be optimized in three categories:

The first category is the p-median problem: A classic problem which consists of locating p facilities (medians) in a network to minimize the total sum of the distances from each demand node to its nearest median (Senne &Lorena, 2003). Also known as Minisum method, it has application in the construction of facilities for the provision of non-emergency services, such as schools, hospitals, post offices, banks, among others. The second category is p-Centres problem: Also known as Minimax, this problem consists of specifying p Centres to minimize the maximum distance (or time) that any user needs to travel to get to the facilities. P-Centre problems are most applicable in the urban emergency services, such as those of medical care emergency, firefighting and repair service emergencies;

The last category is Set Covering Problem (SCP): It is used in emergency and non-emergency services. It aims to select those facilities which cover the set of demand points, having as measure of performance; a critical distance predetermined service for displacement. According to Larson and Odoni (2007), this model is more general than the other two aforementioned.

In order to achieve the proposed goal in this work, which is to identify the emergency exit points in a railway tunnel located in the city of Maringa-PR, the set covering problem is going to be used, based on the fact that this methodology can provide a coverage of areas that demand assistance in critical situations.

2.3 Set Covering Problem (SCP)

One of the ways for solving facility location problems, when there are requirements to be complied, is by using the methodology of SPC (Lobo & Gonçalves, 2004). In this model, the focus is to find the smallest number of facilities to be installed so that all demand points are allocated to at least one of the facilities.

The SPC (Larson & Odoni, 2007) as follows: consider a set \( V = I \cup J \) nodes in a graph \( G \), where \( I = \{1, 2, ..., m\} \) is the set of demand nodes and \( J = \{1, 2, ..., n\} \) is the set of candidate nodes to the facilities. Given a service distance \( \lambda \) specified so any location \( j \in J \) can reach the demands \( i \in I \), the SCP can be formulated as an integer linear programming problem, mathematically defined as

Minimize

\[
\sum_{j=1}^{n} c_j x_j
\]

Subject to

\[
\sum_{j=1}^{n} a_{ij} x_j \geq 1 \quad \forall \ i = 1, ..., m \tag{2}
\]

\[
x_j \in \{0,1\} \quad \forall \ j = 1, ..., n \tag{3}
\]
where \( c_j \) is the unit cost associated with the variable \( x_j \), \( a_{ij} = 1 \) if demand point \( j \) is covered by a unit \( i \), minus the distance \( \lambda \) or \( a_{ij} = 0 \) otherwise. Restriction (2) ensures that any \( j \) will be covered by at least one installation, and the restriction (3) states that \( x_j = 1 \) if the column \( j \) compose the solution or \( x_j = 0 \) otherwise.

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### 2.4 Characterizing the study area

The city of Maringá is located in the northwest of the Paraná State. Founded on May 10, 1947, it had its urban design traced by Eng. Jorge Macedo Vieira. The city of Maringá has an urbanization rate of 98.20% (IPARDES, 2012), being the third largest city in the State of Paraná once it has a population of 357,077 inhabitants (IBGE, 2012) and a density of 744.87 hab./Km² (IPARDES, 2012).

The fast process of city expansion was mainly due to its prime location. There was a process of urban restructuring in the city, designed to establish a new urban concept. The studies of changes began in 1985, but it was in 1995 that the New Centre Project was started, in order to improve traffic flow in the downtown area.

Thus, the implementation of railway tunnel over the lowered railway line was necessary for the process of urbanization in the New Centre, making the central area traffic more agile and secure. So, the railroad was lowered and the city was unified. The downgrade of the tracks within the city limits of Maringá also made possible the deployment of a modern avenue named Horácio Raccanello, which was built over the concrete slab of the tunnel, accelerating the development of the central area, attracting real estate projects for the area. The project was implemented in parts, and it is still running. It has 7000 meters of extension, with 17 meters of wide and 10 meters of high. This is illustrated, schematically, in Figure 1.

There are ten avenues crossing Horácio Raccanello Av., and several others were opened to have better connection between the north-south regions of the city. Figure 2 illustrates its stretch, highlighting the residential, institutional, commercial and industrial areas.

As mentioned before, the security mechanisms for the tunnel and its surroundings it was not projected. So there is no emergency exits (access points to the tunnel), system identification of smoke or artificial lighting in the tunnel. In case of accident, fire fighting vehicles would have to travel about two kilometers over the railway line to enter in the site. The high temperatures and the lack of oxygen can cause deformations in the concrete structure, causing surface reflections, in other words, part of the tunnel could collapse.
The current problem existing in the city of Maringá - PR, led to the one responsible for the 5th Group of the Fire Department from the City staff to insert, in the Public Ministry, some documents stating as a primary factor, the inclusion of access points to the tunnel in case of any accident occurs. Thus, this work contributes towards to the city of Maringá, by pointing out the favourable access points to the tunnel, since, as it can be seen from Figure 2, there are several high density areas, which leave the entire population of this region vulnerable and, in case of accidents, it may have large proportions, which may cause great difficulty for rescuers.

2.5 Model proposed the "New Centre Project" Maringá-PR Brazil

Based on this study, it was schemed a graph, which presents the main collected data to achieve the proposed goals in this work. The construction of the graph (Figure 3) was based on the real scenario, so the candidates to be access points are the intersections between streets or avenues crossing Horácio Raccanello Ave (it also could be seen as black lines in Figure 2).

![Figure 3. Graph based on the study scenario.](image)

To understand better the proposed "New Centre Project Centre" model, the application variables to be used in the scenario are as follow:
- Set of candidates to be access points to the tunnel (P2 to P9);
- Set of existing access points (P1 and P10);
- Set of traffic generators hubs (K1 to K12);
- \( D_{ij} \) distance matrix between points \( i,j \in L \);
- \( V_{ij} \) distance matrix between traffic generators hubs \( i \in K \) and \( j \in J \) access points;

Thus, the objective of this model is to select, among the set of candidate points, which ones will be most favourable to construct emergency accesses, to meet all the related section to the tunnel, reducing the distances that are travelled by emergency responders in the event of an accident. The inherent risks to the population who transits the region and the already existing access points were also considered. A mathematical modelling is given by

Minimize

\[
\sum_{j=1}^{n} \frac{x_j}{c_j} \quad (4)
\]

Subject to

\[
x_j = 1 \quad \forall j \in L \quad (5)
\]

\[
\sum_{j=1}^{n} \alpha_{ij} x_j \geq 1 \quad \forall i = 1, ..., m \quad (6)
\]

\[
x_j \in \{0, 1\} \quad \forall j \in J \quad (7)
\]

where \( a_{ij} = 1 \) if point \( i \) can be covered by an access point \( j \) within a distance of service \( \lambda \) or \( a_{ij} = 0 \) otherwise; \( x_j \; \forall j \in J \cup L \) are the decision variables, with \( x_j = 1 \) if point \( j \) is part of the solution and \( x_j = 0 \) if not. Consequently, the restriction (5) ensures that all existing points \( j \in L \) will be part of the solution. Restriction (6) ensures that all \( j \) must be covered by at least one installation and the restriction (7) is the binary variable.

The unit cost is defined as \( 1/c_j \) because the higher the cost, the higher the risk and also the higher the possibility of choosing a particular access point \( j \). In this paper, it is proposed by the composition of the cost \( c_j \) as follows

\[
c_j = D_j + AQ_j + PG_j + DF_j \quad (8)
\]

where \( D_j \) is the population density of the area which belongs to the point \( j \); \( AQ_j \) is a penalty applied according to the degree of heating of the stretch where the point is, in other word, there is some curves in the stretch where
the air circulation is impaired and the heat level is high; \( PG_j \) is an index that defines the influence of all traffic generators hubs of the study area to the access point candidate \( j \) and its formulation is given by

\[
PG_j = \frac{1}{\sum_{i \in K} v_{ij}}
\]

being \( v_{ij} \) the distance between the hub \( i \) and the point \( j \); and \( p_i \) is the maximum number of people traveling by \( i \). That is, the influence caused by people who enjoy some service such as the greater the distance, the lower the degree of influence of a individual hub. \( DF_j \) is a difficulty measure of access by rescue teams given by the distance between them and the currently existing access points, so its mathematical composition is given by

\[
DF_j = \min_{l \in L} d_{lj}
\]

where \( d_{lj} \) is the distance between \( l \) and \( j \) in \([D_{lj}]\). It should be noticed that all values must be normalized.

### 2.6 Model Application

In order to test the performance of the proposed model, it is presented here the data used in its application. By emphasizing that the data collection was based on the application scenario, according to the graph showed in Figure 3. The set of exiting access points are on both ends of Horacio Raccanello Ave., represented by points P1 and P10. The distance matrix between the candidate accesses points used in this study is presented in Table 1.

#### Table 1. Matrix of distances (in meters).

<table>
<thead>
<tr>
<th>Street / Avenue</th>
<th>P1*</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>P9</th>
<th>P10*</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 de Dezembro</td>
<td>1100</td>
<td>0</td>
<td>700</td>
<td>350</td>
<td>0</td>
<td>350</td>
<td>970</td>
<td>1450</td>
<td>1900</td>
<td>2390</td>
</tr>
<tr>
<td>Paraná</td>
<td>1100</td>
<td>0</td>
<td>700</td>
<td>350</td>
<td>0</td>
<td>350</td>
<td>970</td>
<td>1450</td>
<td>1900</td>
<td>2390</td>
</tr>
<tr>
<td>Duque de Caxias</td>
<td>P3</td>
<td>1450</td>
<td>350</td>
<td>0</td>
<td>350</td>
<td>970</td>
<td>1450</td>
<td>1900</td>
<td>2390</td>
<td>2800</td>
</tr>
<tr>
<td>Herval</td>
<td>P4</td>
<td>1800</td>
<td>700</td>
<td>350</td>
<td>0</td>
<td>350</td>
<td>970</td>
<td>1450</td>
<td>1900</td>
<td>2390</td>
</tr>
<tr>
<td>São Paulo</td>
<td>P5</td>
<td>2150</td>
<td>1050</td>
<td>700</td>
<td>350</td>
<td>0</td>
<td>620</td>
<td>1100</td>
<td>1550</td>
<td>2040</td>
</tr>
<tr>
<td>Pedro Taques</td>
<td>P6</td>
<td>2770</td>
<td>1670</td>
<td>1320</td>
<td>970</td>
<td>620</td>
<td>0</td>
<td>480</td>
<td>930</td>
<td>1420</td>
</tr>
<tr>
<td>Monlevard</td>
<td>P7</td>
<td>3250</td>
<td>2150</td>
<td>1800</td>
<td>1450</td>
<td>1100</td>
<td>480</td>
<td>0</td>
<td>450</td>
<td>940</td>
</tr>
<tr>
<td>Rebouças</td>
<td>P8</td>
<td>3700</td>
<td>2600</td>
<td>2250</td>
<td>1900</td>
<td>1550</td>
<td>930</td>
<td>450</td>
<td>0</td>
<td>490</td>
</tr>
<tr>
<td>Gaspar Ricardo</td>
<td>P9</td>
<td>4190</td>
<td>3090</td>
<td>2740</td>
<td>2390</td>
<td>2040</td>
<td>1420</td>
<td>940</td>
<td>490</td>
<td>0</td>
</tr>
<tr>
<td>Tuiuti</td>
<td>P10*</td>
<td>4600</td>
<td>3500</td>
<td>3150</td>
<td>2800</td>
<td>2450</td>
<td>1830</td>
<td>1350</td>
<td>900</td>
<td>410</td>
</tr>
</tbody>
</table>

(*) Existing points of access.

The population density \( D_j \) was estimated according to the area and the type of building found in the place; the value of stretch heating degree \( AQ_j \) was evaluated according to environmental conditions, such as lack of ventilation by using values between 0 and 10, where 0 is no risk of heating and 10 is the highest heating level. Representative values to \( D_j \) and \( AQ_j \) are shown in Table 2, and as the P1 and P10 are currently existing access points, they were not accounted.

#### Table 2. Population Density and Degree Heating of candidate access points.

<table>
<thead>
<tr>
<th>Point</th>
<th>D</th>
<th>AQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>4.000</td>
<td>2</td>
</tr>
<tr>
<td>P3</td>
<td>7.500</td>
<td>3</td>
</tr>
<tr>
<td>P4</td>
<td>63.700</td>
<td>4</td>
</tr>
<tr>
<td>P5</td>
<td>8.570</td>
<td>6</td>
</tr>
<tr>
<td>P6</td>
<td>32.000</td>
<td>5</td>
</tr>
<tr>
<td>P7</td>
<td>3.700</td>
<td>2</td>
</tr>
<tr>
<td>P8</td>
<td>4.800</td>
<td>2</td>
</tr>
<tr>
<td>P9</td>
<td>6.000</td>
<td>2</td>
</tr>
</tbody>
</table>

For definition of \( PG_j \) it was calculated the distance between all traffic generators hubs and the point \( j \), as well as the maximum number of people who travel in each pole. With these data, it was possible to identify the difficulty of access points compared to 12 existing trip generator poles on site under study. These hubs are composed by eight educational institutions (two colleges and six pre-college preparatory courses); two trade Centre (one being the shopping mall with the largest circulation of people in the city); the only existing municipal bus terminal through which all the bus routes in the city; and the city road Centre. Subsequently, it was held the measurements access difficulty by \( j \) rescue teams due to the distance from the currently existing access points \( DF_j \), according to equation (10). The used data are presented in Table 3.
According to the analysis performed by the city fire department team, in case of an accident, rescuers would have to go about two miles on the railway line to enter the site, so this was the maximum distance chosen to evaluate the model. It was taken therefore simulations with critical distance to verify the coverage between the measured points. It was simulated the coverage from the point of the following critical distances (in meters): 2,000, 1,500, 1,300, 1,000, 800 and 500.

3. RESULTS

Ideally, all points would be covered with smaller critical distance, i.e., all candidates to be access points would be selected and some effective actions would be implemented, however, a possible project with high cost could restrict the proposal. Thus, to simulate these critical distances, and considering that the higher the cost, the higher the risk and also the largest the chance to choose the access point \( j \), the definition of the best points of emergency access covered by the study are shown in Table 4.

Table 3. Distance in meters from the possible access point to the trip generator pole.

<table>
<thead>
<tr>
<th>Points</th>
<th>Difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>1181.7</td>
</tr>
<tr>
<td>P3</td>
<td>1484.6</td>
</tr>
<tr>
<td>P4</td>
<td>1835.7</td>
</tr>
<tr>
<td>P5</td>
<td>2179.7</td>
</tr>
<tr>
<td>P6</td>
<td>2706.3</td>
</tr>
<tr>
<td>P7</td>
<td>3211.9</td>
</tr>
<tr>
<td>P8</td>
<td>3704.4</td>
</tr>
<tr>
<td>P9</td>
<td>4149</td>
</tr>
<tr>
<td>P10</td>
<td>3476.7</td>
</tr>
<tr>
<td></td>
<td>3124.6</td>
</tr>
<tr>
<td></td>
<td>2780.52</td>
</tr>
<tr>
<td></td>
<td>2429.4</td>
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It was shown by the performed simulation that among the candidate to be emergency access points for the railway tunnel, there was a coverage between facilities, i.e., all the points covered other points besides itself, and according to the modelling these points showed coverage service superior to 1, being part of the problem solution.

Another factor to be noted is that only currently existing access points (P1 and P10) unable service agility. With the simulation, in the first scenario studied, it was used the critical distance of 2000 meters, and thus, the point to be designed would be the P4, which is justified, because it is present in other scenarios. This region has the greatest population density, being the point with greatest risk and it is relative centred to the hubs of traffic generators.

However, when observing the various scenarios, it can be seen that by installing just one more emergency access point in the tunnel would not be the most efficient action. Thus, it would be interesting to have at least two points, but not ruling out the possibility of having three points, once in case of an accident occurs at one of the points, there would still be alternatives access and the treatment would be faster.

By analysing the results, it was considered the restriction to limited the adjacent points, in other words, as a result for the critical distance of 500 meters, it was achieved the following access points: P3, P4 and P7, therefore, one should make the option to choose between P3 and P4 point. From these factors, seeking a fast response to emergency help in the tunnel, it was chosen to insert the emergency access point with a critical distance of 800 meters. So it proposes two new emergency access points, would be deployed at P4 and P7 points.

4. CONCLUSIONS

This paper proposed the location of railway tunnel emergency points, more precisely in the New Centre Project in the city Maringa - PR. It was used the Set Covering Problem (SPC) location modelling, based on the fact that
the studied problem has some factors that would favoured to obtain results, such as: the population density of the area; the heating degree of the tunnel due to lack of ventilation, the traffic generator poles as well as the difficulty of access.

With the model, it was possible to identify the points that benefit the quickly access to the tunnel, thereby meeting the proposed objectives. However, it is important to note that the study did not consider the issues related to civil engineering, for example, the geological conditions at the circuit, the infrastructure already existing, the excavation to be held for the opening of access, at last, it was studied just the best places to be deployed.

Another factor to be highlighted is that other means, which are outside of this research scope, would reduce the risks on site, such as the protection fire actions in tunnels emphasized by ABNT NBR 15661: 2012, a Brazilian regulation published in 2012.

As a continuation of this study, as a continuation of this study, it is aimed to assess the outcome of this work by entering the location of the city fire station, in order to evaluate the average response time, as well as to streamline the operation of the emergency team. Another goal is to focus on analysis scenario, which deserves special attention from the government in order to establish contingency plans to ensure greater security and minimize the possible impacts caused to the environment and people.

References


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