# Reengineering of the Emergency Service System from the Point of Service Provider

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Abstract: An emergency service system design is usually worked up by a system administrator, who acts on behalf of the public. Applied objective is either minimal disutility perceived by an average user or disutility perceived by the worst situated user. This paper deals with a completely different case, when partial reengineering is suggested by one of the private service providers running a considerable portion of the current service centers. The provider tries to maximize his profit subject to the system administrator's rules, which should protect public from worsening of their access to the service. We model the provider's behavior and study efficiency of the administrator's rules.

## 1 INTRODUCTION

When a brand new emergency system under limited number of service centers is designed, the used objective is usually to minimize the average or total disutility perceived by the users (Brotcorne et al., 2003, Doerner et al., 2005, Jánošíková and Žarnay, 2014). The optimal deployment of service centers for such type of system can be obtained by exact or approximate solving of the weighted *p*-median problem modelled either by the location-allocation or radial formulations (García et al., 2011, Janáček and Kvet, 2013, Elloumi et al., 2004, Sayah and Irnich, 2016). The initial emergency system design is mostly suggested by so-called system administrator, who represents interests of public. The interests may have various forms, e.g. minimal average response time or minimal response time of the worst situated user etc. The administrator usually supervises dispatching of emergency vehicles to individual users' demands in the way that each user demand is served from the nearest available service center. The service provision by emergency vehicles is performed by private providers, who own and run several service centers equipped with emergency vehicles.

As distribution of demands for service develops in time and space, the originally determined center locations will cease to suit both serviced population and providers. These discrepance can be mitigated in different ways. In some national or local emergency systems (Reuter-Oppermann et al, 2017, Guerriero et al, 2016), the system administrator is responsible for the reengineering. In other national systems, e.g. the emergency health care system of the Slovak Republic, the system administrator only defines some rules, under which a service provider is allowed to relocate his service centers (Kvet and Janáček, 2016). In the mentioned emergency health care system the profit of a provider is proportional to transportation performance necessary for the demand satisfaction.

In this paper, we study the recent case, when the considered provider's objective of reengineering is to maximize his profit submit to the administrator rules.

As the users' and providers'objectives are in a conflict, the user protecting rules comprise usual condition that the average or total value of disutility must not exceed a given limit and also disutility perceived by the worst situated user cannot be worsen. Additionally, some further rules can be imposed on the process of reengineering, e.g. at most a given number of center location can be changed, or each center location can be moved only in a given radius from its original possition.

Following these rules, a considered provider, who performs reengineering, will change locations of his centers so that he maximizes the profit by



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capturing much demand under assumption that each demand is serviced from the nearest service center.

In this paper, we provide a reader with linear programming model of provider's reengineering of his part of emergency service system to maximize his profit under rules imposed by the system administrator. As the maximization of the considered provider's profit must not be performed by servicing a demand from the more distant providers'center than necessary, a special constraints must be implemented in the model. That is why, we perform a computational study, to find whether real-sized instances of the problem are solvable using a common IP-solver. We also compare the variants of the approach to reengineering, when the volume of transportation performance represents the provider's profit.

## 2 MODEL OF PROVIDERS' REENGINEERING

Coming from a conventional denotation of the weighted $p$-median problem, we introduce $J$ as a finite set of all system users, where $b_j$ denotes a volume of expected demand of user $j \in J$. Let $I$ be a finite set of possible center locations. Symbol $d_{ij}$ denotes the integer distance between locations $i$ and $j$, where $i, j \in I \cup J$. The maximal relevant distance is denoted by $m$. The current emergency service center deployment is described by two disjoint sets of located centers $I_L \subset I$ and $I_F \subset I$, where $I_L$ contains $p$ centers of the considered provider, who performs reengineering and $I_F$ is the set of the centers belonging to the other providers.

The system administrator's rules are quantified by the following constants. The value $F$ gives upper limit of the total transportation performance necessary for satisfaction of all users' demands (the total disutility perceived by system users). The value $H$ is the maximal feasible distance between a user's location and the nearest service center. The symbol $D$ denotes the maximal distance between a current center location and the possible new location of the center. The integer $w$ gives the maximal number of centers from $I_L$, which are allowed to change locations.

To be able to formulate the model in a concise way, we derive several auxiliary structures. Let $N_t=\{i \in I\text{-}I_F\text{: } d_{ti} \leq D\}$ denote the set of all possible center locations, to which the center $t \in I_L$ can be moved. Similarly, let $S_i=\{t \in I_L\text{: } i \in N_t\}$ denote a set of all centers of the considered provider, which can be moved to $i \in I_R$. The subset $I_R \subseteq I\text{-}I_F$ is defined by the formula $I_R = \bigcup_{t \in I_L} N_t$. Realize that $t \in N_t$ and $i \in S_i$ for $t \in I_L$ and $i \in I_R$ and thus $I_L \subset I_R$.

We introduce coefficients $a^s_{ij}$ for each pair $i$, $j$ $i \in I_R \cup I_F$ and $j \in J$, where $a^s_{ij} = 1$ if and only if $d_{ij} \leq s$ and $a^s_{ij} = 0$ otherwise for $s = 0, 1, \ldots, m$-1.

We define cost coefficients for $i \in I_R$ and $j \in J$ so that $c_{ij} = 0$ if $d_{ij} \geq min\{d_{tj}\text{: } t \in I_F\}$ and $c_{ij} = b_j d_{ij}$ otherwise.

The last two auxiliary structures are denoted as $\{P_j\}$ and $\{R_j\}$, where $j \in J$. The first of them is a system of ordered lists, where list $P_j$ consisting of $i \in I_R$ is ordered so that the following inequalities hold: $d_{P_j(1)j} \leq d_{P_j(2)j} \leq \cdots \leq d_{P_j(|I_R|)j}$. An element $R_j$ of the second structure is an ordered list of subscripts from range 1, …, $|I_R|$, where $R_j(r)$ gives the minimal subscript, for which $d_{P_j(r)j} < d_{P_j(R_j(r))j}$ holds. Obviously $r+1 \leq R_j(r)$.

Now, we introduce series of decision variables, where binary variable $y_i$ defined for each $i \in I_R$ takes the value of one, if a service center is to be located at $i$ and it takes the value of zero otherwise.

The reallocation variable $u_{ti} \in \{0, 1\}$ for $t \in I_L$ and $i \in N_t$ takes the value of one, if the service center at $t$ is to be moved to $i$ and it takes the value of zero otherwise.

To be able to express the total transportation performance value, we introduce zero-one auxiliary variables $x_{js}$ for $j \in J$ and $s = 0, 1, \ldots, m$-1, where $x_{js} = 1$ if there is no located service center in the radius $s$ from the user location $j$.

Finally, we introduce series of allocation variables $z_{ij} \in \{0, 1\}$ for $i \in I_R \cup I_F$ and $j \in J$, where $z_{ij} = 1$ if user demand located to $j$ is serviced from center location $i$.

Using the above introduced structures and decision variables, we suggest the following model.

$$Maximize \sum_{j \in J} \sum_{i \in I_R} c_{ij} z_{ij} \tag{1}$$

$$Subject\ to \sum_{i \in I_R} y_i = p \tag{2}$$

$$\sum_{i \in I_L} y_i \geq p - w \tag{3}$$

$$\sum_{i \in N_t} u_{ti} = 1 \quad for\ t \in I_L \tag{4}$$

$$\sum_{t \in S_i} u_{ti} \leq y_i \quad for\ i \in I_R \tag{5}$$

$$\sum_{i \in I_R} a^H_{ij} y_i + \sum_{i \in I_F} a^H_{ij} \geq 1 \quad for\ j \in J \tag{6}$$

$$x_{js} + \sum_{i \in I_R} a_{ij}^s y_i + \sum_{i \in I_F} a_{ij}^s \geq 1 \quad for\ j \in J,\ s = 0,\dots,m-1 \qquad (7)$$

$$\sum_{j \in J} b_j \sum_{s=0}^{m-1} x_{js} \leq F \qquad (8)$$

$$\sum_{i \in I_R \cup I_F} z_{ij} = 1 \quad for\ j \in J \qquad (9)$$

$$z_{ij} \leq y_i \quad for\ j \in J,\ i \in I_R \qquad (10)$$

$$1 - y_{P_j(k)} \geq \sum_{r=R_j(k)}^{|I_R|} z_{P_j(r)j} \quad for\ j \in J,\ k = 1, \dots, |I_R| - 1 \qquad (11)$$

$$y_i \in \{0, 1\} \quad for\ \ i \in I_R \qquad (12)$$

$$u_{ti} \in \{0, 1\} \quad for\ \ t \in I_L,\ i \in N_t \qquad (13)$$

$$x_{js} \in \{0, 1\} \quad for\ \ j \in J,\ s = 0, \dots, m-1 \qquad (14)$$

$$z_{ij} \in \{0, 1\} \quad for\ i \in I_R \cup I_F,\ j \in J \qquad (15)$$

The objective function (1) expresses the volume of transportation performance allocated to the considered provider (provider's profit). If a user is nearer to a center of other providers, the contribution to the considered provider is zero. The misallocation of a user to a more distant center of the considered provider is prevented by constraints (11).

Constraint (2) preserves constant number of centers belonging to the considered provider under reengineering.

Constraint (3) limits the number of changed center locations by the constant *w*.

Constraints (4) allow moving the center from the current location *t* to at most one other possible location in the radius *D*.

Constraints (5) enable to bring at most one center to a location *i* subject to condition that the original location of the brought center lies in the radius *D*. These constraints also assure consistency among the decisions on move and decisions on center location.

Constraints (6) ensure that any user *j* lies in the radius *H* from a located center, i.e. maximal distance between a user and the nearest center is less than or equal to the value *H*.

Constraints (7) give relation between located variables $y_i$ and auxiliary variables $x_{js}$ so that $x_{js}$ equals to one, if no center is located in the radius *s* from the user's location *j*. Then, the expression $x_{j0}+ x_{j1}+\dots+ x_{jm-1}$ gives the distance from the user *j* to the nearest service center regardless of its owner.

Constraint (8) makes use of the variables $x_{js}$ and assures that the total transportation performance does not exceed the given value *F*.

Constraints (9) are commonly used allocation constraints, which assure that each user demand is allocated to exactly one center belonging either to the considered provider or to other providers.

Link-up constraints (10) give relation between allocation variables $z_{ij}$ and the location variables $y_i$, which model the decisions on locating service centers operated by considered provider.

Constraints (11) were developed to prevent the maximization process from allocating a demand to a more distant service center than the nearest one. The constraint formulated for location $P_j(k)$ and user *j* forbids allocation of user's *j* demand to every service center $P_j(r)$, which is more distant from the location *j* than the center location $P_j(k)$.

## 3 COMPUTATIONAL ASPECTS OF THE APROACH

The original approach to the public service system design (Current et al., 2002, Marianov and Serra, 2002) is based on solving the weighted *p*-median problem. The scheme of the former approaches consists in problem formulation by means of integer linear programming and subsequent submission of the problem to some solver equipped with a universal branch-and-bound method. To overcome the computational complexity emerging, when real-sized instances of the problem were solved, the radial formulation (García et al., 2011, Janáček, 2008) was developed. Then, the emergency service system can be successively designed by solving the problem (16), (2), (7), (12) and (14).

$$Minimize \sum_{j \in J} b_j \sum_{s=0}^{m-1} x_{js} \qquad (16)$$

The proper function of the model is based on the fact that the optimization process minimizing (16) presses down values of the individual variables $x_{js}$. Then the value of expression $x_{j0} + x_{j1} +\dots+ x_{jm-1}$ corresponds to the shortest integer distance from the user *j* to the nearest located center. If some other constraints are appended to the model (16), (2), (7), (12) and (14), it may or need not lead to considerable elongation of computational time necessary for reaching the exact solution.

Whereas, addition of the constraints (4) and (5) almost do not impact the computational time (Kvet and Janáček, 2016), subjoining capacitated constraints may considerably spoil the computational process convergence (Janáček and Gábrišová, 2009). Other types of constraints deteriorating the computational process are min-max link-up constraints used, when a robust service system is designed employing detrimental scenarios (Janáček and Kvet, 2017).

In comparison with the classical models of the emergency system design problem, we have to face the difficulty caused by maximization of the objective function modelling the transportation performance (provider's profit). Whereas the classical objective minimizes the transportation performance and thus a user is associated with the nearest located center (see Figure 1), the maximization considered in our paper may lead to the assignment depicted in Figure 2.

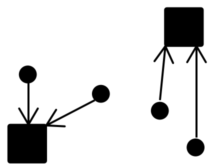

Figure 1: In the chart, the black circles represent locations of user demands and the black squares depict locations of service centers. The arcs correspond to the assignment of the demands to the centers, which minimizes the total travel distance.

The assignment in Figure 1 fully fulfils the assumption that each user must be serviced from the nearest service center, but the assignment in Figure 2 completely breaks the assumption.

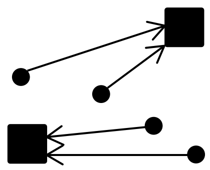

Figure 2: In the chart, the black circles represent locations of user demands and the black squares depict locations of service centers. The arcs correspond to the assignment of the demands to the centers, which maximizes the total travel distance.

To avoid the misassignment, we developed a series of constraints, which prevent user's demand from assignment to a more distant located service center than the nearest one. The series of constraints for a given user $j$ has $|I_R|$-1 members, where $|I_R|$ denotes the number of possible center locations, to which the user demand can be assigned. The constraint construction comes from the idea that if there is a location $i^*$ equipped with a service center distant $d_{i^*j}$ from the user $j$, then the demand of user $j$ must not be assigned to any location $i$, which meets $d_{ij} > d_{i^*j}$. To formalize the constraint, we order all possible center locations from $I_R$ increasingly according to their distance from $j$ so that the list $P_j(1)$, $P_j(2)$, ..., $P_j(|I_R|)$ gives the ordered sequence of the center locations. Thus $d_{P_j(r)j} \leq d_{P_j(r+1)j}$ holds for each $r$ =1, …, $|I_R|$-1. The case of tie, i.e. $d_{P_j(r)j} = d_{P_j(r+1)j}$, is handled by mapping $R_j$, where $R_j(r)$ gives the minimal subscript from the range 1, …, $|I_R|$ such that $d_{P_j(\mathrm{r})j} < d_{P_j(R_j(r))j}$ holds. If no such subscript exists, the $R_j(r)$ is set at the value $|I_R|$+1. Having defined $P_j(r)$ and $R_j(r)$ for $r$ = 1, 2, …, $|I_R|$, we can construct the constraint in the way that if a center is located at the location $P_j(r)$, then any assignment of the demand of user $j$ to any of center locations of $P_j(R_j(r))$, $P_j(R_j(r)+1)$, …, $P_j(|I_R|)$ must be forbidden. In the constraint formulation (11), we make use of the convention that sum over the empty range, i.e. the range, which starts with higher subscript than the ending one, is defined as zero value.

For given $j$, $|I_R|$-1 constraints must be formulated. This way, the model has to be enlarged by $|J|$*($|I_R|$-1) constraints ensuring the proper demand assignment.

Based on the above-mentioned experience, we have to raise the question of technical solvability of the formulated problem (1)-(15). We ask whether a commercial solver based on the branch-and-bound technique is able to find the exact solution of a real-sized problem in acceptable time.

# 4 EMERGENCY SERVICE POLICY ISSUES OF THE APPROACH

The presented approach deals with the special case of emergency system reengineering, when a considered service provider is allowed to change the deployment of his service centers submit to rules, which are determined by the system administrator. Respecting the rules, the considered provider naturally aims to increase his profit, which is proportional to the traveled distance. It is obvious that the provider's objective is in conflict with the system user objective.

Thus, the upcoming changes of the service center deployment are matter of negotiation between the two mentioned players. The administrator can set up the general rules of the system adjustment and the considered provider suggests the location changes of operated centers.

The suggested model together with a suitable IP-solver represent such a tool, which can enable the negotiation under knowledge of consequences both rules and provider's behavior. As the considered rules are quantified by the values of *F*, *H*, *w* and *D*, the provider can find, what is the optimal profit under the values and thus, he can conclude whether the changes pay off.

As concerns the system administrator, the tool, which models the provider's behavior, enables to investigate the provider's profit under given values *F* and *H*. Starting with some default values, e.g. the transportation performance and the worst distance between a user and the nearest center obtained for the original center deployment, the administrator can repeat the solving algorithm with step by step decreased values and he can suggest such values, which improve service accessibility for users and also let the considered provider increase the profit. Another issue of the tool for the administrator is represented by a possibility to test effectiveness of the auxiliary and formal rules *w* and *D* from the point of users' benefit.

# 5 COMPUTATIONAL STUDY

To study presented approach to reengineering of the emergency service system, we performed series of numerical experiments, in which the optimization software FICO Xpress 8.0 (64-bit, release 2016) was used and the experiments were run on a PC equipped with the Intel® Core™ i7 5500U processor with the parameters: 2.4 GHz and 16 GB RAM.

Used benchmarks were derived from real emergency health care system, which was originally implemented in eight regions of Slovak Republic. For each self-governing region, i.e. Bratislava (BA), Banská Bystrica (BB), Košice (KE), Nitra (NR), Prešov (PO), Trenčín (TN), Trnava (TT) and Žilina (ZA), all cities and villages with corresponding number $b_j$ of inhabitants were taken into account. The coefficients $b_j$ were rounded to hundreds. The set of communities represents both the set *J* of users' locations and the set *I* of possible center locations as well. The cardinalities of these sets are reported in Table 1, where the associated column is denoted by $|I|$. The total number of located centers is given in the column denoted as *TNC*. The network distance from a user to the nearest located center was taken as the user´s disutility.

Table 1: Size of used benchmarks.

| Region | $\|I\|$ | *TNC* |
|---|---|---|
| BA | 87 | 14 |
| BB | 515 | 36 |
| KE | 460 | 32 |
| NR | 350 | 27 |
| PO | 664 | 32 |
| TN | 276 | 21 |
| TT | 249 | 18 |
| ZA | 315 | 29 |

An individual experiment was organized so that the current deployment of service centers for each self-governing region was studied first. The obtained results are summarized in Table 2. The total transportation performance was computed as a sum of weighted distances between system users and the nearest located service centers. The weights were set to the number of users sharing the same location. The values of the total transportation performance are reported in column denoted by "Total TP". For each self-governing region, ten different instances were generated randomly. These instances differ in the list of located service centers operated by the considered provider. The average percentage ratio of the provider's centers to all centers is reported in the column denoted by "Prov. [%]". The right part of Table 2 denoted by "Max TP decrease" contains the results of analysis aimed at computing the maximal possible decrease of the total transportation performance, which can be achieved by relocating some of the provider's service centers. To determine these values, the model (1)-(15) was simplified. The objective function value (1) was replaced by minimization of the left part of the constraint (8), whereas constraint (8) was completely excluded from the model. The constraints containing variables $z_{ij} \in \{0, 1\}$ for $i \in I_R \cup I_F$ and $j \in J$ were not taken into account, because they were not needed. Other constraints stayed unchanged. The value of parameter *w* was set to the cardinality of the provider's service center list. It means that all centers operated by the considered provider could change their location. The value of *D* was set to 15 according to the rule applied in the emergency health care system of the Slovak Republic (Kvet and Janáček, 2016). The value of *H* was set to the maximal value of distance between a user and the nearest located service center in the current design.

By solving the adjusted model, we obtained the minimal value of transportation performance, which can be obtained by reengineering. The average computational time in seconds necessary for problem solving is denoted by "Time [s]".The last column of the table denoted by “Dec. [%]” contains the maximal possible percentage decrease of the total transportation performance, where the current value reported in the column “Total TP” was taken as the base.

Table 2: Analysis of current centers deployment and possible improvement of total transportation performance.

| Region | Current state | | Max TP decrease | |
|---|---|---|---|---|
| | Total TP | Prov. [%] | Time [s] | Dec. [%] |
| BA | 21842 | 55.1 | 0.02 | 6.34 |
| BB | 32476 | 44.9 | 0.21 | 2.40 |
| KE | 36363 | 46.0 | 0.36 | 3.21 |
| NR | 38831 | 50.7 | 0.48 | 3.94 |
| PO | 42740 | 44.3 | 0.28 | 1.59 |
| TN | 26683 | 52.9 | 0.12 | 2.50 |
| TT | 31582 | 49.6 | 0.13 | 4.92 |
| ZA | 31955 | 46.8 | 0.11 | 3.49 |

The obtained results summarized in Table 2 indicate that the reengineering of the emergency service system may bring considerable benefit for the system users. The model for maximal possible improvement of the total transportation performance is easily solvable and the computational process does not take more than 0.5 second.

The next portion of numerical experiments was aimed at studying the characteristics of suggested model (1)-(15) described in the previous sections. Since the previous experiments enabled us to get the range, in which the total transportation performance may vary, the following case study was suggested to answer the question, how the constraint (8) influences the computational process of solving the model (1)-(15). The experiments were organized in the following way. For each solved instance, 6 problems were solved. The models differed in the value of $F$ used in the constraint (8). The parameter $F$ was set in such a way, that the total transportation performance was reduced by 0, 20, 40, 60, 80 and 100 percent of its possible range. The upper bound of mentioned range is represented by the transportation performance computed for current deployment of service centers (see column “Total TP” in Table 2) and the lower bound can be obtained as the result of mathematical model searching for the maximal possible decrease of the total transportation performance using the simplified model described above.

The characteristic of the reengineering model studied in this contribution consists in the considered provider’s profit, which is to be maximized under the condition that the total transportation performance is limited by the value of $F$. The obtained results are reported in Table 3, which follows the structure of previous tables. The provider’s profit is expressed in percentage of current provider’s transportation performance. The negative values indicate such solution, in which the reengineering process brings worse situation for the considered provider, i.e. the resulting provider’s profit is less than his current profit.

Table 3: Average percentage profit of the provider's transportation performance for individual regions and given percentage reduction of transportation performance.

| Reg\Red | 0 | 20 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|---|
| BA | 19.6 | 14.3 | 10.5 | 5.4 | 0.6 | -9.4 |
| BB | 10.5 | 8.5 | 6.3 | 3.8 | 1.0 | -2.3 |
| KE | 20.8 | 17.7 | 14.4 | 11.2 | 7.3 | -3.1 |
| NR | 23.6 | 21.1 | 18.3 | 15.3 | 11.5 | 4.3 |
| PO | 10.8 | 9.2 | 7.0 | 3.8 | 1.7 | -1.0 |
| TN | 13.8 | 11.6 | 9.0 | 6.0 | 1.8 | -3.4 |
| TT | 23.4 | 20.2 | 17.1 | 13.5 | 8.1 | 1.3 |
| ZA | 16.3 | 14.2 | 10.8 | 8.3 | 4.7 | -1.5 |
| **AVG** | **17.5** | **14.8** | **11.9** | **8.7** | **4.9** | **-1.4** |

The dependency of average percentage profit of the considered provider on percentage reduction of the total transportation performance is shown in Figure 3. These results confirm our expectations that the provider's profit decreases with increasing reduction of transportation performance. Negative values indicate that the provider may worsen the current provider’s profit.

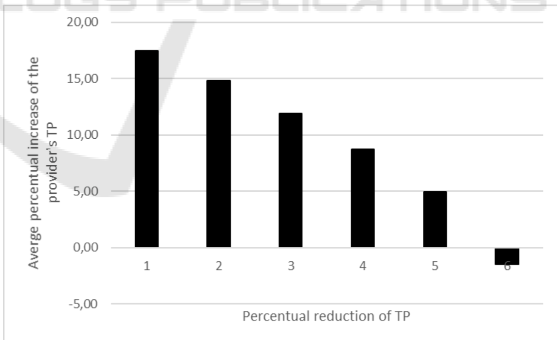


Figure 3: Dependency of average percentage profit of the considered provider on percentage reduction of the total transportation performance.

Finally, the reengineering process may have a secondary impact. Even if the main goal of changing the provider’s center locations is to maximize the provider’s profit, the obtained solution may bring improvement also for the system users. As we have shown, the total transportation performance can get lower and thus, the average user distance to the nearest located service center decreases. Table 4 summarizes the average user distances for different percentage reduction of transportation performance.

Table 4: Average user's distance for individual regions and given percentage reduction of transportation performance.

| Reg\Red | 0 | 20 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|---|
| BA | 3.60 | 3.55 | 3.50 | 3.46 | 3.41 | 3.38 |
| BB | 4.91 | 4.89 | 4.87 | 4.84 | 4.82 | 4.80 |
| KE | 4.59 | 4.56 | 4.53 | 4.50 | 4.47 | 4.44 |
| NR | 5.63 | 5.58 | 5.54 | 5.49 | 5.45 | 5.41 |
| PO | 5.22 | 5.21 | 5.19 | 5.17 | 5.16 | 5.14 |
| TN | 4.49 | 4.47 | 4.44 | 4.42 | 4.40 | 4.38 |
| TT | 5.67 | 5.62 | 5.56 | 5.50 | 5.45 | 5.40 |
| ZA | 4.62 | 4.59 | 4.56 | 4.53 | 4.49 | 4.46 |
| **AVG** | **4.84** | **4.81** | **4.77** | **4.74** | **4.70** | **4.67** |

The results confirm that even if the improvement of average user distance is not significantly high, the reengineering process may bring some benefit also for the system users. The dependency of average user distance on percentage reduction of total transportation performance computed for all solved instances is shown in the Figure 4.

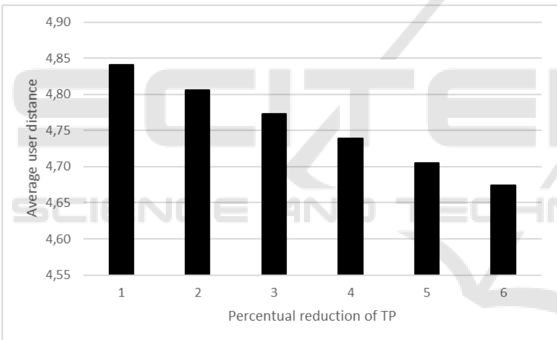


Figure 4: Dependency of average user distance on percentage reduction of total transportation performance.

As concerns computational time, we have observed that the time necessary for solution of the problem (1)-(15) was in orders higher than that one of the simplified version reported in Table 2. Nevertheless, we have found that the time has never exceeded the limit of three minutes.

## 6 CONCLUSIONS

The paper deals with an approach to emergency service system reengineering, where change of the service center deployment is performed by one of the providers with the goal to maximize his profit. The system administrator, who imposes some constraints on the provider's decisions, protects users' interests. The approach is based on the suggested model, which includes new form of restricted assignment constraints. We showed that the complex problem described by the model is solvable in acceptable computational time even if real-world instances of the problem are solved. Performing numerical experiments with benchmarks derived from current state of service centers deployment, we obtained and presented information about possible users' disutility improvement and the associated provider's profit. The presented approach may serve as a very useful tool for possible negotiation of the system administrator with the service provider concerning system reengineering and sharing the resulting benefit among system users and the service provider.

Future research may be aimed at usage of the suggested modelling technique in game modelling, in which different groups of providers compete for the profit under system administrator supervision.

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