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WORKING PAPER

Finding the adequate location scenario after the merger of fire brigades thanks to Multiple Criteria Decision Analysis Methods

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Finding the adequate location scenario after the merger of fire brigades thanks to Multiple Criteria Decision Analysis Methods

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Abstract

This paper addresses the issue of selecting a suitable location for a fire station in canton of Fribourg, as a result of a fire brigades' merger, by applying Multiple Criteria Decision Analysis (MCDA) methods. Solving the problem of determining fire station locations through various methods has been analyzed in-depth by researchers. However, a different approach, based on application of methods like ELECTRE and PROMETHEE is advanced in this paper.

The selection of the most suitable fire station site is obtained by applying the designated methods to five distinctive alternatives (called *scenarios*), taking into consideration the relatively limited information and specifics, and the extensive number of relevant criteria that summed up to seventy-eight.

Taking the merger of the three local fire departments as an example, the proposed methods for selecting a suitable location for the fire station demonstrate and justify the reason behind this choice. Research shows that the applied methods have been proven to be useful and powerful tools that exhibited acceptable levels of consistency when selecting the best project. The main finding is that one scenario in particular proved to be strongly dominant over the others and most suitable in determining the fire station location.

Keywords

Multiple Criteria Decision Analysis (MCDA), ELECTRE, PROMETHEE, criteria, weights, alternative evaluation, ranking, fire station location, merger.

1. Introduction

Presently in Switzerland, in most municipalities, firefighting and personal rescue are carried out by a fire brigade. If some cities have professionals among their firefighters, villages cannot afford such a costly structure and must rely on volunteer firefighters. Unfortunately, recruiting volunteers is becoming increasingly difficult as their number is steadily declining.

In the canton of Fribourg, the local government is currently encouraging municipalities to regroup their forces through mergers. Thus, over the span of two decades, the number of municipalities in the canton decreased from 246 in 1997 to 136 in 2017 [Eta17]. In the event that a merger is not planned in the short term, ECAB[1] (Etablissement cantonal d'assurance des bâtiments du canton de

[1] *Etablissement cantonal d'assurance des bâtiments* (ECAB) is the legal authority responsible for insuring all the buildings in the canton of Fribourg and promoting the prevention and defense against fire and natural elements. http://www.ecab.ch/ecab/fr/pub/ecab.htm

Fribourg) has the task of proposing a collaboration agreement or even a merger between the fire brigades of geographically proximate municipalities.

However, the collaboration or the merger may generate problems: on one hand, the need to coordinate practices that are sometimes different (operating like in the "good old days", different type of management for each fire brigade, location of fire stations). On the other hand, other problems are highlighted, such as a lack of documentation concerning the processes in place, a complete absence of job specifications or a merger proposal without official guidelines.

This paper focuses on the fire station location problem. In the case of a collaboration agreement or a merger, is it necessary to maintain the existing infrastructure, which may generate unnecessary costs, or do new alternatives have to be analyzed in order to be more efficient? Among the different alternatives, at least two scenarios may be highlighted: the *one fire station* (all-in-one) and *new and existing fire stations* (mix old-new). The main objective of this study is to apply two different families of MCDA outranking methods, namely ELECTRE and PROMETHEE, and to compare the outcome.

The reminder of the paper is organized as follows: after a brief state of the art of the literature dealing with the fire station location problem in Section 2, the methodology for defining and choosing the best alternative is described in Section 3. As this selection process is a typical Multi-Criteria Decision Analysis (MCDA) problem, Section 4 is dedicated to a brief overview of two famous MCDA methods. Section 5 details the main steps of the MCDA approach implemented to solve the fire station location problem for the specific collaboration case of the fire departments of three municipalities of Sarine district (Avry, Matran and Neyruz) and introduces the best scenario retained. A set of observations is presented in Section 6. Finally, Section 7 contains the conclusion.

2. State of the art

In this section, a literature review will briefly present the main methods applied for solving the problem of determining fire station location (see the synthesis provided in Table 1), with a specific attention for AHP and GIS.

AHP (Analytic Hierarchy Process) is a mathematical MCDA method that derives ratio scales from paired comparison of criteria and allows for some small inconsistencies in judgments. It is possible to use measurements or subjective opinions as inputs for this method. More details on the AHP can be found in [Goe13]. [DiM16] applied a hybrid type method, AHP-ELECTRE, in order to simulate the need to build a new fire barrack. While AHP approach is appropriate for quantifying a combination of qualitative information and quantitative data, the GIS deals with geospatial data that provides complementary relevant information to decision makers.

GIS (Geographic Information System) is a widely accepted and popular system put into service in several domains such as determining optimal geographic locations, navigation, global mapping, disaster management, etc. This system is utilized to store and display data related to positions of several items on the surface of a land. It can show different kinds of data and multiple layers of information on one map, such as streets, buildings, and trees [Nat17]. The input data for GIS are either spatial (geographic location of features) or non-spatial (descriptive or numeric information about features) [Col00]. The interested reader can find additional information in [ESR07] and [Dem17]. Several scientific papers focused on GIS in determining locations: [Lin12] drew on GIS location allocation analysis, maps and spatial information technologies in station optimization study; [Che12] used GIS together with risk modeling approach for locating fire stations in Belgium and [Sen11] implemented a GIS approach to fire station location selection in Antalya.

Some studies combined both GIS and AHP methods: [Erd10] in a multi-criteria site selection for fire services in Istanbul, [Das14] in modeling the suitability analysis to establish new fire stations in Erbil, and [Wei11] in studying and implementation of fire sites planning.

References	Solution approaches
[Kan08]	Sophisticated methodology tool called ArcGIS Spatial Analyst in a study on the location of Ottawa fire stations.
[Ric82]	Preliminary analysis applying the p-median method for the fire station locations in the province of Luxembourg (Belgium).
[Vol11]	Spatial analysis methodology in two phases for the relocation of the Metropolitan Fire Brigade in Melbourne (MFB) fire stations.
[Sch81]	Road network approach, set covering approach and simulation in the application of a location model to fire stations in Rotterdam.
[Kol74]	Computer based method and heuristic method for the dynamic relocation of fire companies in New York City.
[Mur13]	Several modeling approaches to optimize the spatial location of urban fire stations.
[Yan07]	Fuzzy multi-objective programming for optimization of fire station locations through genetic algorithms.
[Nou13]	Linear assignment method for locating fire stations in Maku City.
Multiple criteria oriented approaches	
[Bad98]	Multi-criteria modeling approach to locate fire stations via integer goal programming, using conflicting criteria.
[Deg12]	Multi-criteria approach MILP (mixed integral linear programming) for the location of fire departments.
[Gra13]	Weighted scoring of alternatives against selected criteria to choose the location of the Nantucket central fire station.

Table 1 – Overview on the various solution approaches

This review shows that there is not any dominant applied method to be used for fire station location problem. However, multiple criteria modeling seems appealing for most studies.

As the problem addressed in this study is clearly a problem of multi criteria analysis (see Section 3: Context and Methodology), the choice of applying outranking methods for finding a solution is quite natural. In consequence, the ELECTRE and PROMETHEE families of methods will be briefly described in Section 4: Methods Overview.

3. Context and Methodology

The fire departments of Avry, Matran, and Neyruz witnessed an unprecedented level of collaboration during the past years. Given the significant reduction in staff numbers across the fire departments in Fribourg canton, ECAB proposes, through the FriFire[2] reform, a merger into a single inter-municipal fire brigade with a sole operating and investment budget. In order to enhance efficiency, as well as centralization of management and control, a merger project between the fire departments of the three municipalities is suggested ("CSPi M.A.N." being the name of the new entity). Another motive for the merger is to reduce the workload. Presently the same administrative activities are performed

[2] The main objective of the FriFire reform is to regionalize the fire defense and to concentrate the resources. A strong constraint is a response time within 15 minutes since a fire alarm is acknowledged with a minimum of 8 firefighters.

at the level of each municipality, while this could be reduced to single intervention by the municipality in charge of accounting and financial matters.

Nonetheless, one of the arising problem and challenge of the proposed merger is the location of the fire stations (if a new location is required at all). Currently, each municipality has its own fire station, but what would be the optimal number of fire stations after the merger? And where should these stations be located? This paper seeks to answer this question and solve the problem for the new potential location for the fire station(s) under many different weighted criteria. To do so, different scenarios (or alternatives) will be tested and evaluated against all related criteria using the following steps:

1) Define the scenarios, e.g. set up a new location and abandon the old stations, or retain one station and build a new station.
2) Define main categories of criteria that are essential for the location and the relevant sub-criteria, e.g. establishment cost or technical criteria. Sub-criteria are represented by acquisition cost, development cost, location, response time, etc.
3) Assign weights for all criteria and sub-criteria, considering that criteria do not have the same importance. For instance, security criteria and response time are much more important than aesthetical concerns.
4) Develop a program to solve the problem using direct MCDA tools for ELECTRE family.
5) Rank the preference of all scenarios according to the solutions obtained from the applied methods and draw a conclusion.

Notice that, if the word “alternative” is commonly used in the MCDA literature, the word “scenario” is preferred here, as a scenario may contain sometimes more than one action, which is not often the case with an alternative.

4. Methods Overview

The methods that are briefly described in this paper are ELECTRE and PROMETHEE families. They are called “families” as they group together a set of related methods (see table 2). These are the two most prominent outranking approaches that focus on pairwise comparison of alternatives. The ELECTRE family was developed by Roy in the mid ‘60s [Roy68], while the PROMETHEE family was elaborated by Brans at the beginning of the ‘80s [Bra82]. The ELECTRE family methods differ according to the complexity, the availability of information and the nature of the problem, while PROMETHEE family methods use a preference function of the difference in performance levels on criteria for pairwise alternatives. Several standard shapes of the preference function with different parameters can be used. For more details about these methods, the reader is advised to check [Bel02], [Zop10] and [Fig05].

The starting point for these methods is the matrix that shows the performance of all alternatives against all criteria taking into consideration the weights of criteria. ELECTRE I generates concordance and discordance matrices where alternatives are the axis, then concordance and discordance thresholds are decided to determine the preference of alternatives over each other. The concordance index $C(a,b)$ is the quantification of positive arguments that measures the strength of the hypothesis that alternative a is at least as good as alternative b. The discordance index $D(a,b)$ is the quantification of negative arguments that measures the strength of evidence against the hypothesis. Consequently, an outrank matrix is generated and a kernel set of alternatives is selected such that these alternatives are preferred to the others. However, no difference or preference is provided to help choose the best alternative among them. ELECTRE II (an updated version of

ELECTRE I) aims to produce a ranking of alternatives instead of just providing a set of most preferred alternatives. The method employs two sets of outranking relations considering two different sets of concordance and discordance thresholds; namely: strong outranking and weak outranking. The strong outranking adopts strict thresholds, while weak outranking takes on rather moderate thresholds. Strong and weak outrank matrices appear as a result, then a procedure is performed with these two matrices to rank alternatives.

Methods	**References**	**Characteristics / Specificities**
ELECTRE – Elimination Et Choix Traduisant la REalité		
ELECTRE I	[Roy68]	Designed for selection problems: selecting a smallest set of best alternatives
ELECTRE Iv	[May94]	ELECTRE I with veto threshold (true-criteria)
ELECTRE Is	[Roy84]	Generalization of ELECTRE Iv: modeling situation in presence of inaccurate data (pseudo-criteria)
ELECTRE II	[Roy71]	Designed for ranking problems: embedded outranking relations sequence (true-criteria)
ELECTRE III	[Roy78]	Designed for ranking problems: fuzzy binary outranking relations (pseudo-criteria)
ELECTRE IV	[Roy82]	Designed for ranking problems without the use of relative criteria importance coefficients
ELECTRE TRI	[Wei92], [Roy93]	Tool designed to deal with sorting alternatives into ordered categories (limiting profiles). Method based on boundary actions
ELECTRE TRI-B	[Alm10]	Renaming of ELECTRE TRI to avoid confusion with ELECTRE TRI-C
ELECTRE TRI-C	[Alm10]	New sorting method that follows a decision aiding constructive approach: each category is defined by a single reference action (central profiles)
ELECTRE TRI-NC	[Alm12]	New sorting method which takes into account several reference actions for characterizing each category
PROMETHEE - Preference Ranking Organization METHods for Enrichment Evaluations		
PROMETHEE I	[Bra82]	Partial ranking of alternatives based on flows (choice problems)
PROMETHEE II	[Bra82]	Complete ranking of alternatives (best to worst) based on net flow (ranking problems)
PROMETHEE III	[Bra86]	Complete ranking of alternatives based on intervals
PROMETHEE IV	[Bra84], [Bra86]	Complete or partial ranking of alternatives when the set of viable solutions is continuous
PROMETHEE V	[Bra92]	MCDA including segmentation constraints
PROMETHEE VI	[Bra95]	Sensitivity analysis procedure: representation of the "human brain"
PROMETHEE GDSS	[Mac98]	Designed to help a group of decision-makers to achieve consensus
PROMETHEE GAIA	[Mar88], [Bra94]	Visualization of problem characteristics through geometrical interpretations (graphical representation of results)
PROMETHEE TRI	[Fig04]	Designed to treat sorting problems
PROMETHEE CLUSTER	[Fig04]	Designed to treat clustering problems

Table 2 – Overview of ELECTRE and PROMETHEE family methods

When more input data can be used such as preference, indifference and veto thresholds, ELECTRE III (a more complex extension of ELECTRE II) is recommended. Note that PROMETHEE is a very similar approach to ELECTRE III that takes into consideration preference and indifference thresholds and provides a ranking of alternatives.

5. Application of MCDA Approach

As ELECTRE and PROMETHEE methods are rather similar in terms of inputs, approach in addressing the problem and provided results, the application hereunder will be focused only on ELECTRE. The application of ELECTRE family will be following the five steps of the methodology described before.

5.1. Scenarios definition

The managers in charge and the experts have identified five reasonable scenarios for the future implementation of the fire stations. The scenarios are as follows:

Scenario 1: *Three fire stations*

Retaining the existing 3 fire stations located in each municipality: Avry, Matran and Neyruz. The premises belong to each municipality based on territorial limits.

Scenario 2: *Two fire stations*

Relocating Matran's firefighters and equipment to Avry. Matran's fire station will be made available to the "Young firemen of Sarine" (Jeunes Sapeurs-Pompiers de la Sarine - JSPS).

The existing premises in Avry will be remodeled in order to accommodate all of Matran's equipment and staff: construction of a new locker-room area, toilets for women, new garage door, etc.

The fire station in Neyruz is kept in place. A respiratory-protection (RP) cell will be installed inside the existing fire station.

Scenario 3: *One fire station*

Relocating the firefighters and the equipment of Matran and Neyruz to Avry. As the existing space is not big enough to accommodate all staff and equipment, an extension is planned. Several options are possible:

Option 1: use extra space from other municipality services located in the same building

Option 2: use the whole space from other municipality services located in the same building

Option 3: build an extension of the existing building (other municipality services keep their spaces)

Scenario 4: *New fire station*

Construction of a new fire station for the new fire brigade "CSPi M.A.N.". Determine the optimal service area.

The new fire station should meet all the criteria that were previously studied and selected. If an existing building meets the established criteria, it is possible to consider the acquisition and transformation of this building into a new fire station. Two options are therefore possible:

Option 1: construct a new building

Option 2: acquire an existing surface and transform it accordingly

Scenario 5: *New and existing fire stations*

Keep one or more existing fire stations and build or acquire a surface for a new fire station that meets the criteria.

The map in Appendix 1 shows the location of the city of Fribourg and the three municipalities. Fribourg's city limits and its fire station site are shown in purple, while the area of concern is bordered in red. Red circles on the map mark the actual location of the three fire stations and the green circle represents one of the possible new locations.

5.2. Criteria definition

The selection of relevant criteria was not by any means an easy task. Identified criteria fall into six major categories: establishment costs, operating costs, technical criteria, administrative criteria, economic and social criteria, and other criteria. Each of these categories has its own criteria and sub-criteria. All projects guarantee a response time of 15 minutes as per the requirements of the FriFire reform.

The complete list of criteria categories and criteria, followed by a brief description, is presented in Appendix 2. Note that the final number of criteria sums up to 78. A synthesis of the six major categories is highlighted in Table 3.

Establishment Costs	**Operating Costs**	**Technical**	**Administrative**	**Economic & Social**	**Other**
Acquisition	Start-up and Running	Location	Subsidies	Need for a New Station	Professionalism
Development	Intervention Failure	Transportation Network	Political Matters	Future Expansion & Adaptation	Effectiveness
Construction & Transformation	Depreciation & Amortization	Response Time	Public Opinion	Population	Reliability
		Coverage & Accessibility	Fiscal & Financial	Environmental Issues	Stochasticity & Robustness
		Risks		Economy of Scale	Sustainability
				Other usage	

Table 3 - Main Criteria Categories

5.3. Weights assignment and projects assessment

Due to the nature of this project and the large number of stakeholders involved, evaluations for the five scenarios against the 78 criteria should be ideally performed by several specialists. However, in this study, the evaluation of one expert will be considered when applying the solution methods. Other outcomes might be generated if other evaluations are to be taken into account in the future.

The weighting process takes into the account that each category has different importance (relative percentage with sum of the weights equal to 100), and each criterion has its own weight within its category (the evaluation guide is explained in Table 4). Both values are multiplied and divided by 10 to give the relative weight of the criterion. For example, for criterion number 1, the category weight is 15 and the criterion weight is 4, this gives 15*4 = 60 (we divide by 10 to keep numbers simpler) then "6" is the relative weight of criterion number 1.

The complete list of evaluations of all alternatives against all criteria with their relative weights according to the expert is presented in Appendix 3, while an abstract is presented in Table 5.

5.4. Software development

In order to provide a user-friendly tool to municipalities, that will allow to easily bring, when required, changes to scenarios, criteria and weights, the development of an Excel based program has been preferred over the purchase of a commercial software.

This Excel based software contains the following methods: ELECTRE I, ELECTRE II, ELECTRE III, PROMETHEE I and PROMETHEE II.

Importance of criterion	Corresponding weight	Performance	Assigned Score
Extremely important	7	Perfect	3
Very important	6	Very good	2
Important	5	Good	1
Average	4	Moderate	0
Weak	3	Bad	-1
Very weak	2	Very bad	-2
Not important	1	Catastrophic	-3

Table 4 - Evaluation Guidelines

					Scenarios and *scores*				
Category	**Criterion Number**	**Category Multiple**	**Criterion Weight**	**Relative Weight**	**1**	**2**	**3**	**4**	**5**
Establishment Costs	1	15	4	6	*2*	*2*	*0*	*2*	*0*
	2	15	3	4.5	*1*	*1*	*1*	*2*	*1*
	3	15	5	7.5	*0*	*1*	*2*	*1*	*0*
	4	15	2	3	*-1*	*2*	*2*	*-1*	*0*
	5	15	3	4.5	*1*	*2*	*0*	*0*	*1*

Table 5 - Evaluation of Alternatives

5.5. Finding the best scenario

Starting from the evaluation of projects, it is possible to apply the ELECTRE I method to provide a set of favorable alternatives for the problem. The concordance and discordance matrices are shown in Table 6. The outrank relations and kernel sets with the parameters C^* and D^* are shown in Figure 1.

The analysis shows that Scenario 4 is clearly the dominant solution for almost all sets of concordance and discordance parameters. It is not easy to determine with ELECTRE I the second best alternative since it is not the objective of this method. However, for doing so, Scenario 4 must be deleted from Table 4 and the ranking relations between projects have to be recalculated. Hence, the existence or removal of any alternative in the set will probably impact the final outcome of the analysis, no matter how good or bad it performs.

By conducting the analysis for the four alternatives (excluding Scenario 4), the outcomes cannot decide on one dominating solution. For each set of concordance and discordance parameters, a different kernel set was generated, mostly with no difference in between alternatives. This might be due to the close performance of the compared alternatives, and partly to the simplicity of ELECTRE I that allows in its outrank relations a double outrank. This issue was addressed in the later version ELECTRE II.

The final conclusion of ELECTRE I for this problem is that Scenario 4 is the dominant solution with no other preference amongst the remaining alternatives. The use of ELECTRE II is highly recommended.

Concordance	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Scenario 1	1.00	0.57	0.62	0.42	0.60
Scenario 2	0.75	1.00	0.78	0.39	0.92
Scenario 3	0.67	0.63	1.00	0.49	0.68
Scenario 4	0.91	0.94	0.94	1.00	0.98
Scenario 5	0.76	0.88	0.77	0.35	1.00
Discordance	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Scenario 1	0.00	0.32	0.40	0.40	0.40
Scenario 2	0.33	0.00	0.27	0.33	0.17
Scenario 3	0.33	0.33	0.00	0.50	0.33
Scenario 4	0.17	0.12	0.12	0.00	0.06
Scenario 5	0.33	0.16	0.27	0.27	0.00

Table 6 - Concordance and Discordance Matrices

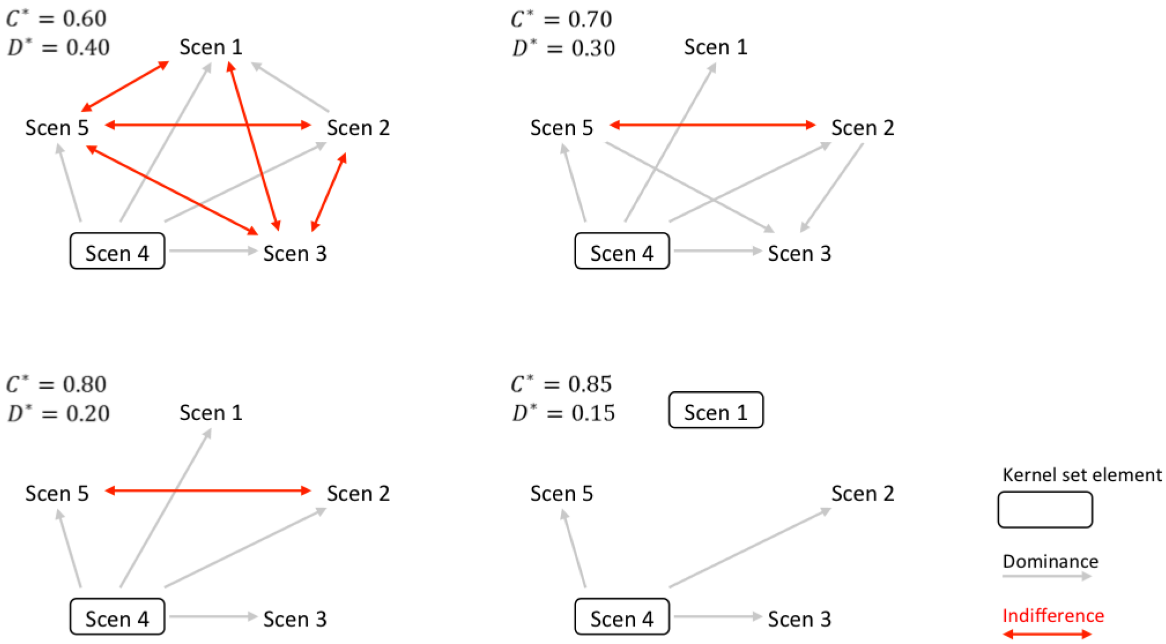

Figure 1 - Outrank Relations and Kernel Sets

The starting point of ELECTRE II is the same as in ELECTRE I. The values used are the same like in Table 5 and Table 6. Strong and weak concordance and discordance thresholds are chosen as follows (additional sets of thresholds are considered in the analysis):

$$C^* = 0.80, D^* = 0.30, \qquad C^- = 0.6, D^- = 0.40$$

The strong and weak outrank relations are shown in Table 7.

Strong Outrank	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Scenario 1	0	0	0	0	0
Scenario 2	0	0	0	0	1
Scenario 3	0	0	0	0	0
Scenario 4	1	1	1	0	1
Scenario 5	0	0	0	0	0
Weak Outrank	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Scenario 1	0	0	0	0	0
Scenario 2	1	0	1	0	1
Scenario 3	1	0	0	0	0
Scenario 4	1	1	1	0	1
Scenario 5	1	0	1	0	0

Table 7 - Strong and Weak Outrank Relations

Consequently, the generated two preorders and final order for the mentioned parameters and other sets of parameters are presented in Table 8. Note that all sets of tested thresholds resulted in the exact orders. This order brings enough evidence that Scenario 4 is the dominant solution followed by Scenario 2.

Threshold Values				Descending Preorder	Ascending Preorder	Final Order
C^*	0.80	0.90	0.75	Scenario 4	Scenario 4	Scenario 4
D^*	0.30	0.25	0.20	Scenario 2	Scenario 2	Scenario 2
C^-	0.60	0.65	0.55	Scenario 5	Scenario 5	Scenario 5
D^-	0.40	0.35	0.45	Scenario 3	Scenario 3	Scenario 3
				Scenario 1	Scenario 1	Scenario 1

Table 8 - Ranking of Alternatives ELECTRE II

The method ELECTRE III is rather too sophisticated (at least for the project under study) and requires a big amount of additional inputs. For instance, it requires a veto threshold value and a preference threshold for each of the 78 criteria used.

6. Observations

The application of ELECTRE I and II is relatively easy because the method is rather simple in terms of calculations and does not require too much inputs and provides a clear preference of alternatives. The ELECTRE I solution is robust only for the most preferred alternative (Scenario 4) but unclear in giving a preference for the remaining alternatives, while the results of ELECTRE II are very direct in their preference, as Scenario 4 being the best alternative followed by the other alternatives as shown in Table 8. Both methods suggested the same solution for the problem. Therefore, the final recommendation for the case study is to select Scenario 4: build a new fire station for the new fire brigade and abandon the old stations.

This paper tried to apply relatively simple methods to find the most appropriate solution for the fire station location problem. ELECTRE I and II were not the only methods applied. The application of methods ELECTRE III and PROMETHEE I and II (despite the difficulty of their inputs and variables) have suggested the same conclusion. Moreover, sensitivity analysis with different threshold values in these non-presented methods did not contradict the solution of ELECTRE I and II. This might be due to two reasons: firstly, these methods (ELECTRE and PROMETHEE) are very similar and secondly, as Scenario 4 performs significantly better than all other alternatives, any evaluation method used would recommend this solution.

7. Conclusion

The MCDA approach proved to be possible and efficient to use, especially with limited data available. The various explored methods showed a good level of consistency. One of the most important reasons to use MCDA methods is the possibility and the ease of assigning and using weights for each criterion. ELECTRE I is rather too simple and its outcomes are of limited benefits, while ELECTRE II gave a more comprehensive comparison and possibility to rank the alternatives. In addition, the sensitivity analysis (selecting different sets of thresholds) performed with ELECTRE II proved that the solution is quite robust. This demonstrates that the final recommendation - suggesting Scenario 4 - is the only reasonable and representative solution to the problem.

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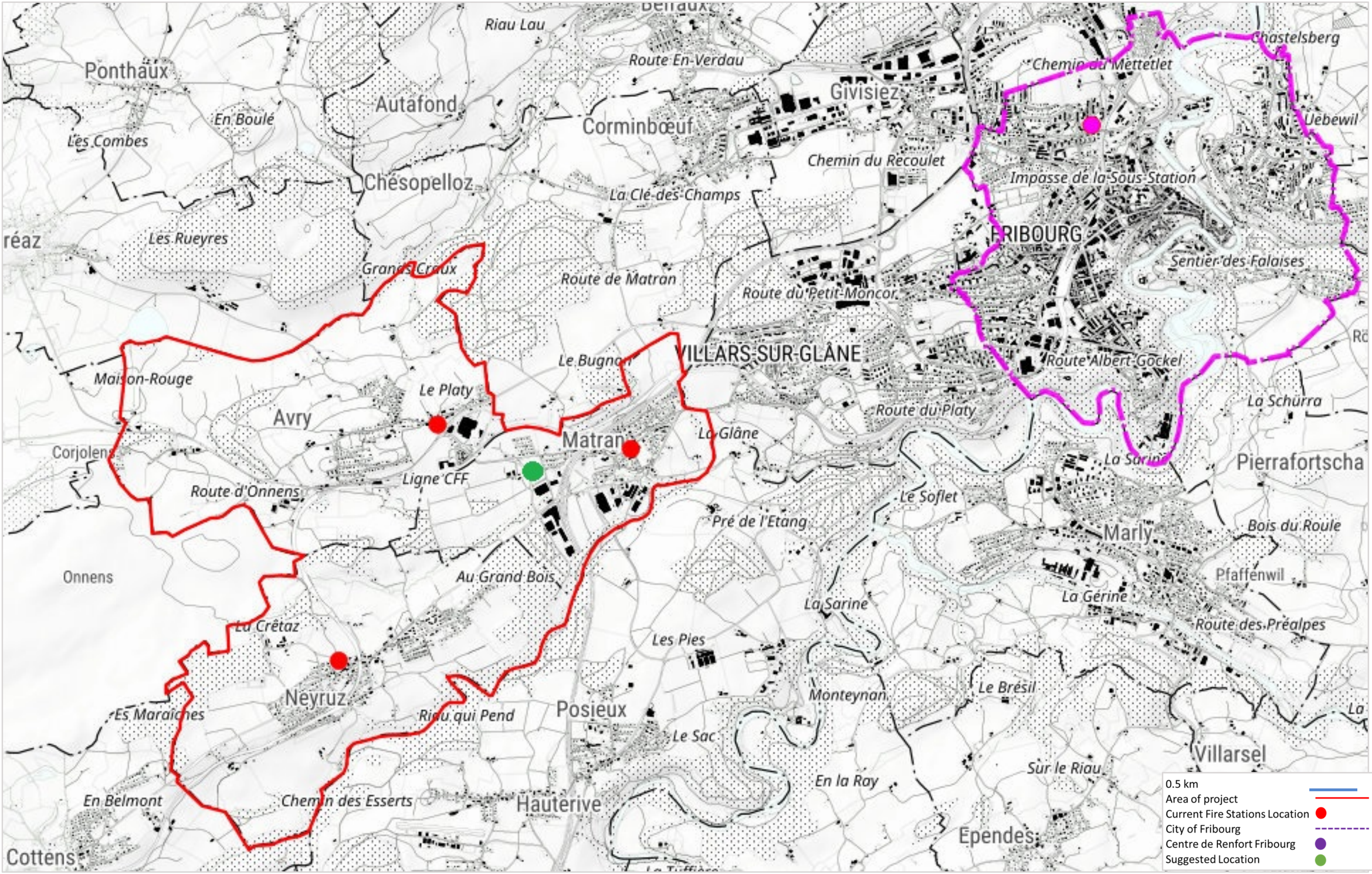
Appendix 1: Map



Appendix 2: Criteria list

A: criterion number **B**: main criteria category **C**: sub-criteria **D**: criteria **E**: comments

A	B	C	D	E
	1. Establishment Costs			
1		*1.1 Acquisition Costs*		
2			1.1.1 land	cost of land
3			1.1.2 existing building	acquisition of an existing building
4			1.1.3 various rights	various rights (property, acquisition, legal, etc.)
5		*1.2 Development Costs*		
6			1.2.1 cost of land development and utilities	all costs associated with land development and utilities (water, hydrants, sewers, gas, etc.)
7			1.2.2 construction of access road	all costs associated with construction of access road
8		*1.3 Construction And Transformation Costs*		
9			1.3.1 construction costs	all costs associated with construction (demolishing, building, etc.)
10			1.3.2 remodeling costs	all costs associates with remodeling / reconfiguring of fire station
	2. Operating Costs			
11		*2.1 Start-Up & Running Costs*		
12			2.1.1 personnel (staff) costs	staff needed to perform all the duties
13			2.1.2 material & equipment (M&E) costs	M&E required by law and special cases
14			2.1.3 installation costs	installation / relocation costs for staff and M&E
15			2.1.4 operating costs	all operations concerning protection against natural hazards (flood, snow, bad weather, earthquake, building resistance to storms, etc.) and fire detection in the fire station (alarm, sprinklers, etc.)
16			2.1.5 maintenance costs	costs associated with the maintenance of facility and M&E
17		*2.2 Intervention Failure Costs*		
18			2.2.1 personal injuries costs	injuries related to interventions, loss of lives
19			2.2.2 material & equipment loss	damage and loss of material & equipment
20			2.2.3 pollution costs	pollution and other environmental hazards
21			2.2.4 property damage costs	damage and loss of personal property (buildings, livestock, personal belongings, etc.)
22		*2.3 Depreciation Costs & Amortization*		
23			2.3.1 costs of assets	costs of all assets
24			2.3.2 value decrease of assets	decrease in value of assets
25			2.3.3 residual assets value	residual value of assets
26			2.3.4 investment life	estimated useful life of assets
27			2.3.5 amortization	reducing the financial debt (loans)
	3. Technical Criteria			
28		*3.1 Location*		
29			3.1.1 geographical barriers	adequate land based on natural conditions: lake, river, slope, elevation, soil texture
30			3.1.2 public facilities accessibility	access to public facilities (schools, hospitals, parks, shopping centers, industrial zones, etc.)
31			3.1.3 territorial development plan (TDP)	TDP developed and approved by the municipality
32			3.1.4 fire station size & layout	size and capacity of the facility
33			3.1.5 proximity to other fire stations	number of other fire stations & closeness (distance)
34			3.1.6 proximity to municipal services & utilities	proximity to municipal services & required utilities (water, hydrants, sewers, gas, etc.)
35		*3.2 Transportation Network*		
36			3.2.1 ease of access to road network	accessibility, future development of the road network (new roads, roundabouts, highway entry/exit, etc.)
37			3.2.2 travel pattern	fluidity of traffic, peak times, level of traffic congestion
38		*3.3 Response Time (RT)*		

A	B	C	D	E
39			3.3.1 max 15 min with 8 firefighters: 80%	FriFire report: maximal delay of 15 min for at least 80% of interventions
40			3.3.2 over 15 min: 20%	FriFire report: only in particular circumstances
41			3.3.3 call / alarm volume	number of calls / alarms received
42		*3.4 Coverage & Accessibility*		
43			3.4.1 area of response coverage	coverage of area by time, distance, number of fire & first-aid units, etc.
44			3.4.2 concentration of resources	concentration of M&E based on existing fire stations
45			3.4.3 accessibility to all sites	accessibility to all sites within the determined response area
46		*3.5 Risks*		
47			3.5.1 social and political risks	not really applicable (strike, war, etc.)
48			3.5.2 community risks	define risk categories, identification of fire hazards, focal points, time differentials (response-time requirement to each risk vs. straight km response), etc.
	4. Administrative Criteria			
49		*4.1 Subsidies*		
50			4.1.1 subsidies from confederation	if applicable
51			4.1.2 subsidies from municipality	if applicable
52			4.1.3 subsidies from state / ECAB	see ECAB guidelines for subsidies
53		*4.2 Political Matters: Laws & Regulations*		
54			4.2.1 state laws & regulations	all laws & regulations in place concerning the firefighters
55			4.2.2 compliance with laws & regulations	compliance at municipality level with all laws & regulations
56		*4.3 Public Opinion*		
57			4.3.1 elections	impact of local elections
58			4.3.2 voting	impact of local & state voting
59		*4.4 Fiscal & Financial Situation*		fiscal conditions & level of financial wealth of municipality
	5. Economic & Social Criteria			
60		*5.1 Importance & Need For A New Fire Station*		community consideration: importance and need for a fire station in the eyes of the municipality & community
61		*5.2 Future Expansion & Adaptations*		possibility of expansion, flexibility, future requirements
62		*5.3 Population*		
63			5.3.1 population structure	pyramid of age, responsiveness & mobility
64			5.3.2 density	density per km^2
65			5.3.3 demographic growth	anticipate significant demographic growth (3 to 10 years)
66			5.3.4 pool of candidates	availability and recruitment of candidates
67		*5.4 Environmental Issues*		
68			5.4.1 pollution hazards	intervention hazards & impact on polluting the environment (water, air, soil, etc.)
69			5.4.2 health hazards & effects	intervention hazards & effects affecting the health of participants (firefighters, police, ambulance. etc.) and other persons involved
70		*5.5 Economies of scale*		
71			5.5.1 M&E utilization rate	utilization rate for all M&E
72			5.5.2 volume of financial benefits	increase in number of services to population vs. money spent on infrastructure & M&E
73		*5.6 Other Usages*		usage for other municipal functions (offices, garage, storage, etc.)
	6. Other Criteria			
74		*6.1 Improve the "professionalism"*		volunteers vs. professionals: in-house training programs & ECAB official courses, aptitude tests, strengths & endurance tests, etc.
75		*6.2 Effectiveness & Efficiency*		level and quality of services
76		*6.3 Reliability*		disruptions: natural disaster or man-made - reliability of the facility & M&E, reliability of services provided
77		*6.4 Stochasticity & Robustness*		flexibility of the decision under the uncertainty of the environment (fire development as disruption in the original state of the event)
78		*6.5 Sustainability*		sustainable fire station (facility location, energy & water conservation, green building & infrastructure, etc.). fire safety and sustainable fire stations often share common goals, but sometimes appear to conflict with each other.

Appendix 3: Evaluations of scenarios

A: criterion number **B**: category multiply **C**: criterion weight **D**: relative weight **1 to 5**: scenarios

A	B	C	D	1	2	3	4	5
1	15	4	6	*2*	*2*	*0*	*2*	*0*
2	15	3	4.5	*1*	*1*	*1*	*2*	*1*
3	15	5	7.5	*0*	*1*	*2*	*1*	*0*
4	15	2	3	*-1*	*2*	*2*	*-1*	*0*
5	15	3	4.5	*1*	*2*	*0*	*0*	*1*
6	15	3	4.5	*2*	*1*	*1*	*2*	*1*
7	15	3	4.5	*2*	*1*	*2*	*1*	*1*
8	15	4	6	*2*	*2*	*1*	*2*	*1*
9	15	4	6	*2*	*1*	*2*	*2*	*1*
10	15	5	7.5	*1*	*1*	*2*	*2*	*1*
11	10	3	3	*0*	*2*	*1*	*0*	*0*
12	10	3	3	*1*	*2*	*2*	*0*	*0*
13	10	4	4	*0*	*2*	*2*	*2*	*2*
14	10	2	2	*2*	*1*	*1*	*1*	*0*
15	10	3	3	*0*	*0*	*1*	*2*	*2*
16	10	3	3	*2*	*2*	*2*	*2*	*1*
17	10	3	3	*-1*	*-1*	*-1*	*0*	*-1*
18	10	3	3	*-1*	*-1*	*-1*	*-1*	*-1*
19	10	3	3	*0*	*0*	*0*	*0*	*0*
20	10	4	4	*0*	*0*	*0*	*0*	*0*
21	10	3	3	*0*	*0*	*0*	*0*	*0*
22	10	3	3	*2*	*2*	*2*	*2*	*2*
23	10	4	4	*1*	*1*	*2*	*2*	*1*
24	10	3	3	*1*	*1*	*2*	*2*	*1*
25	10	2	2	*2*	*1*	*2*	*2*	*1*
26	10	4	4	*2*	*0*	*2*	*2*	*2*
27	10	3	3	*2*	*2*	*2*	*0*	*1*
28	25	5	12.5	*0*	*1*	*-1*	*2*	*1*
29	25	4	10	*-1*	*0*	*-1*	*2*	*0*
30	25	4	10	*1*	*0*	*-1*	*1*	*0*
31	25	4	10	*2*	*0*	*0*	*2*	*0*
32	25	4	10	*-1*	*1*	*2*	*2*	*2*
33	25	2	5	*-1*	*1*	*0*	*1*	*0*
34	25	2	5	*2*	*2*	*2*	*1*	*0*
35	25	5	12.5	*1*	*0*	*-1*	*2*	*1*
36	25	5	12.5	*1*	*0*	*-1*	*2*	*1*
37	25	5	12.5	*0*	*0*	*-1*	*1*	*0*
38	25	5	12.5	*2*	*1*	*0*	*2*	*1*
39	25	5	12.5	*0*	*1*	*0*	*2*	*1*

A	B	C	D	1	2	3	4	5
40	25	4	10	*0*	*1*	*1*	*1*	*1*
41	25	3	7.5	*0*	*0*	*0*	*0*	*0*
42	25	5	12.5	*2*	*1*	*0*	*2*	*1*
43	25	5	12.5	*2*	*0*	*0*	*1*	*0*
44	25	4	10	*0*	*1*	*3*	*3*	*1*
45	25	5	12.5	*1*	*1*	*1*	*1*	*1*
46	25	1	2.5	*0*	*0*	*0*	*0*	*0*
47	25	0	0	*0*	*0*	*0*	*0*	*0*
48	25	2	5	*1*	*1*	*1*	*1*	*1*
49	15	5	7.5	*-1*	*1*	*2*	*2*	*1*
50	15	2	3	*-2*	*2*	*2*	*2*	*2*
51	15	4	6	*-2*	*2*	*2*	*2*	*2*
52	15	4	6	*-2*	*2*	*2*	*2*	*2*
53	15	4	6	*-2*	*1*	*1*	*2*	*1*
54	15	5	7.5	*-2*	*0*	*1*	*2*	*0*
55	15	5	7.5	*-2*	*0*	*1*	*2*	*0*
56	15	4	6	*-1*	*1*	*0*	*1*	*1*
57	15	3	4.5	*-1*	*1*	*0*	*0*	*0*
58	15	4	6	*-1*	*1*	*0*	*0*	*0*
59	15	3	4.5	*0*	*0*	*0*	*0*	*0*
60	20	4	8	*-2*	*0*	*-1*	*1*	*0*
61	20	3	6	*-2*	*1*	*1*	*2*	*1*
62	20	5	10	*2*	*2*	*2*	*2*	*2*
63	20	4	8	*2*	*2*	*2*	*2*	*2*
64	20	5	10	*2*	*1*	*1*	*1*	*1*
65	20	5	10	*2*	*2*	*2*	*2*	*2*
66	20	3	6	*-1*	*2*	*2*	*2*	*2*
67	20	4	8	*1*	*0*	*-1*	*1*	*0*
68	20	4	8	*0*	*0*	*-1*	*2*	*0*
69	20	5	10	*0*	*0*	*-1*	*2*	*0*
70	20	3	6	*0*	*1*	*2*	*2*	*1*
71	20	3	6	*0*	*1*	*2*	*2*	*1*
72	20	3	6	*0*	*0*	*0*	*1*	*0*
73	20	1	2	*0*	*0*	*0*	*0*	*0*
74	15	4	6	*-1*	*0*	*1*	*2*	*0*
75	15	4	6	*-2*	*1*	*1*	*2*	*1*
76	15	4	6	*0*	*1*	*1*	*2*	*1*
77	15	3	4.5	*-1*	*0*	*-1*	*1*	*0*
78	15	4	6	*-1*	*1*	*2*	*2*	*1*