Investigation of impacts of the Transadriatic Pipeline (TAP) Compressor Station location, in the area of Serres Prefecture. Application of a methodology to evaluate alternatives.

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Abstract
The pinpointing of the GCS01 Compressor Station of the Transadriatic Pipeline (TAP) in the plain of Serres, scheduled by TAP AG, may have a series of negative environmental and social impacts. Among these is air pollution, which is expected to increase due to temperature inversion, driving pollutants into the soil and posing a negative cumulative impact on plantations and humans in the Serres Prefecture. Other impacts include excessive noise levels and extensive impacts on nearby settlements in the event of an accident. For these reasons, four alternative locations for GCS01 are proposed, provided that they do not affect protected or high productivity areas: two by the Serres Prefecture, one by local groups and one by the authors. By performing a Multicriteria Decision Analysis and setting the impacts as criteria, it was found that the best location is the one on Kerdyllion Mountain (marked as ANT1) with the second-ranked appropriate location on Mount Vertiskos (GK1). In conclusion, it is clear that the country can benefit from the construction of the TAP pipeline, but it is important to try to avoid significant negative environmental impacts in this planning phase.
Keywords: Multicriteria Decision Analysis Method; natural gas; compressor station; environmental impact; residential settlements.

1. INTRODUCTION

The Transadriatic Pipeline (TAP) project was announced in 2003 and will transport natural gas from Azerbaijan via Turkey, Greece, Albania, Adriatic Sea, Italy to the rest of the European countries. In the Greek territory, TAP is 543 km long and is part of the Southern Gas Corridor, through which 10bcm / year of natural gas will be transported in a life cycle of fifty years. The pipeline starts from Kipi Evros, where the first Compressor Station, GCS00, will be settled.

In the future, the capacity of the Transadriatic Pipeline will be increased from 10 to 20 bcm/year. This increase is going to require the development of a new Compressor Station in the Serres Prefecture, the GCS01, with a power of up to 125 MW and operations based on natural gas use [1]. The GCS01 Compressor Station is planned to consist of five compressors (one of which in stand-by mode), with a 25MW power each, and the required area for the development of their premises is 0.17 km^2 [1]. The proposed locations for the construction of GCS01 by the TAP AG, named TAP1, TAP2 and TAP3, are relatively close to each other and are all situated in the plain of Serres, an area with dense agricultural activity and residential uses, including many nearby settlements.

In the Environmental Impacts Study that was developed by the TAP consortium, emissions and other impacts are presented as complying with acceptable limits [1]. However a strong concern has been expressed by local communities, scientific bodies and others, that the actual impacts will be significantly detrimental. It was supported that another, more appropriate location for the Compressor Station should be proposed. Thus, this paper first examines the validity of the

expressed concerns about possible negative impacts, and secondly it explores and ranks possible alternative locations using a Multicriteria Decision Analysis [2].

1.1 Atmospheric Pollution

The Compressor Station will operate on a 24-hour basis using natural gas, leading to NO_x gas emission. In the area of the Station, NO_x is expected to be recorded from 10 to 20 $\mu g/m^3$ and after construction it is estimated by the TAP company that will reach 50 mg/m^3 before dispersion [1], while the limit for the protection of human health is 40 $\mu g/m^3$ NO_2 and the vegetation protection limit is 30 $\mu g/m^3$ NO_x [3]. Additional emissions are carbon monoxide (CO) while additional emissions include particulate matter (PM2.5) and volatile organic compounds (VOCs) [4] that are currently not considered by the TAP study.

The phenomenon of temperature inversion seems to be intensive in the selected area, since it is a plain's basin surrounded by mountains. During the day, as a result of the earth heating by the sun, instability is caused in the lower part of the atmosphere, which is in contact with the ground. As a result, pollutants are trapped between the earth surface and the tallest stable layer of the atmosphere [5]. This phenomenon deteriorates air pollution and leads to soil acidification as gaseous pollutants are deposited on the soil [6].

Such a type of air pollution has been proven to have negative impacts on human health. More specifically, nitrogen oxides, combined with volatile organic compounds and sunlight, create smog and tropospheric ozone [7]. Inhalation of such smog can cause shortness of breath, wheezing and respiratory problems. It has also been cited as a potential cause of problems, such as asthma and lung malfunction [8]. Concerning the particulate matter PM2.5, its particles have an aerodynamic diameter of equal or less than 2.5 μm and are considered to be the most hazardous, since due to their small size, they are able to reach deeper into the lungs, and may result in respiratory and cardiovascular problems [9]. 90% of the particles are respirable and PM2.5 inhalation causes various forms of pneumoconiosis, asthma, and even in some cases cancer [6].

These negative impacts affect not only humans, but also other species, such as bees. It has been proved that Nitrogen dioxide and oxides of nitrogen (NOx) affect and impair the ability of bees to detect the scent of flowers and therefore their very source of nutrition. This could cause serious negative consequences for the volume of bee colonies and subsequently for the pollination of agricultural crops [10].

Another crucial point is that the MM5 weather model which was used for the Environmental Impacts Study (presented by the TAP consortium) is suitable for locations with an average altitude of 1.500 m., while the location in the Serres plain, where the GCS01 Compressor Station will be constructed, has a 15 m. altitude above sea level and the actual height of the Compressor Station emissions would be at a range between 350 and 400 m. above sea level. Moreover, the HYSPLIT pollutant dispersion model, which was used in the Environmental Impacts Study, forecasts average pollutant concentrations for long periods, but not peak concentrations in short periods of time. It has been reported that one should look at peak exposures, as compared to the averages over longer periods of time, since it seems that they are more biologically relevant if the health effect is triggered by a high, short-term dose rather than a steady dose throughout the day [11]. Last but not least, the data provided by the National Weather Service Station in Serres, which has been in continuous operation for over 50 years, were not connected with or used by the Environmental Impacts Study [12].

1.2 Noise emissions

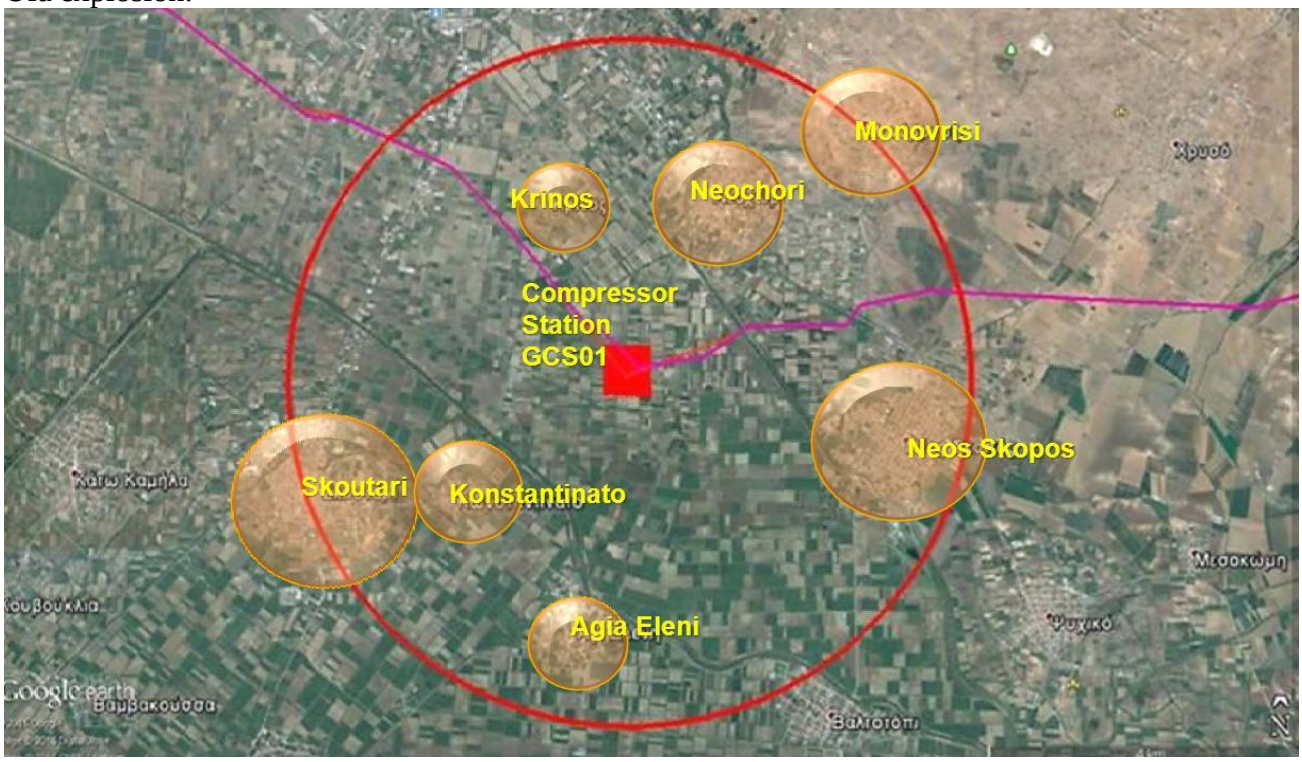
The emitted noise, according to the TAP study, will amount to 65 db (A). This level corresponds to industrial areas, according to Greek Legislation. The selected area is rural, not industrial, with no

background noise, and thus the perceived noise annoyance will be much higher. Hence the maximum permissible limit should be even less than 50 db (A), which is the limit in urban areas [13].

1.3 Accident risk

The risk for accidents is also significant, since in the event of an accident-explosion in a Compressor Station, the radius of the shock wave can reach up 3.5 to 4 km away [12,14], within an area containing many residential settlements. Indicative is the fact that 47% of accidents on gas pipelines are related to compressor stations and facilities, according to the Transportation Safety Board of Canada [15]. Based on recent experience, the zone that may be affected in such an accident is quite extensive [16]; in the 1989 explosion near the Russian city Ufa, the radius of destruction reached 4 km, according to a New York Times report [17]. The affected zone in the plain of Serres, in the case of an accident analogous to the Ufa explosion, is shown in Figure 1. The total population number that will be possibly affected is up to 6720 residents, dispersed in the settlements of Skoutari (2154), Neos Skopos (1934), Neochori (1227), Monovrisi (566), Agia Eleni (476), Konstantinato (332) and Krinos (31), population according to the 2011 Greek census [18].

Figure 1. Radius of destruction in the plain of Serres, in the event of an accident analogous to the Ufa explosion.



The risk could be considered as even higher than the above, as the plain of Serres is a seismogenic area and specifically on a Composite Seismogenic Source (CSS) [19]. In conjunction with seismicity and modern strain data, CSSs can be used for regional probabilistic seismic hazard assessment and for investigating larger-scale geodynamic processes, according to the Greek Database of Seismogenic Sources [19].

1.3 Concluding remarks concerning the proposed TAP locations

Concerning the three, proposed by TAP, alternative locations for the GCS01 Compressor Station, it was concluded that they are connected with a series of possible negative consequences on the area of the Serres plain, hosting dense residential and agricultural activity. Among these are air pollution - expected to increase due to temperature inversion - that will cause deposition of the pollutants on the soil, posing a cumulative negative impact on plants and humans in Serres Prefecture, and the

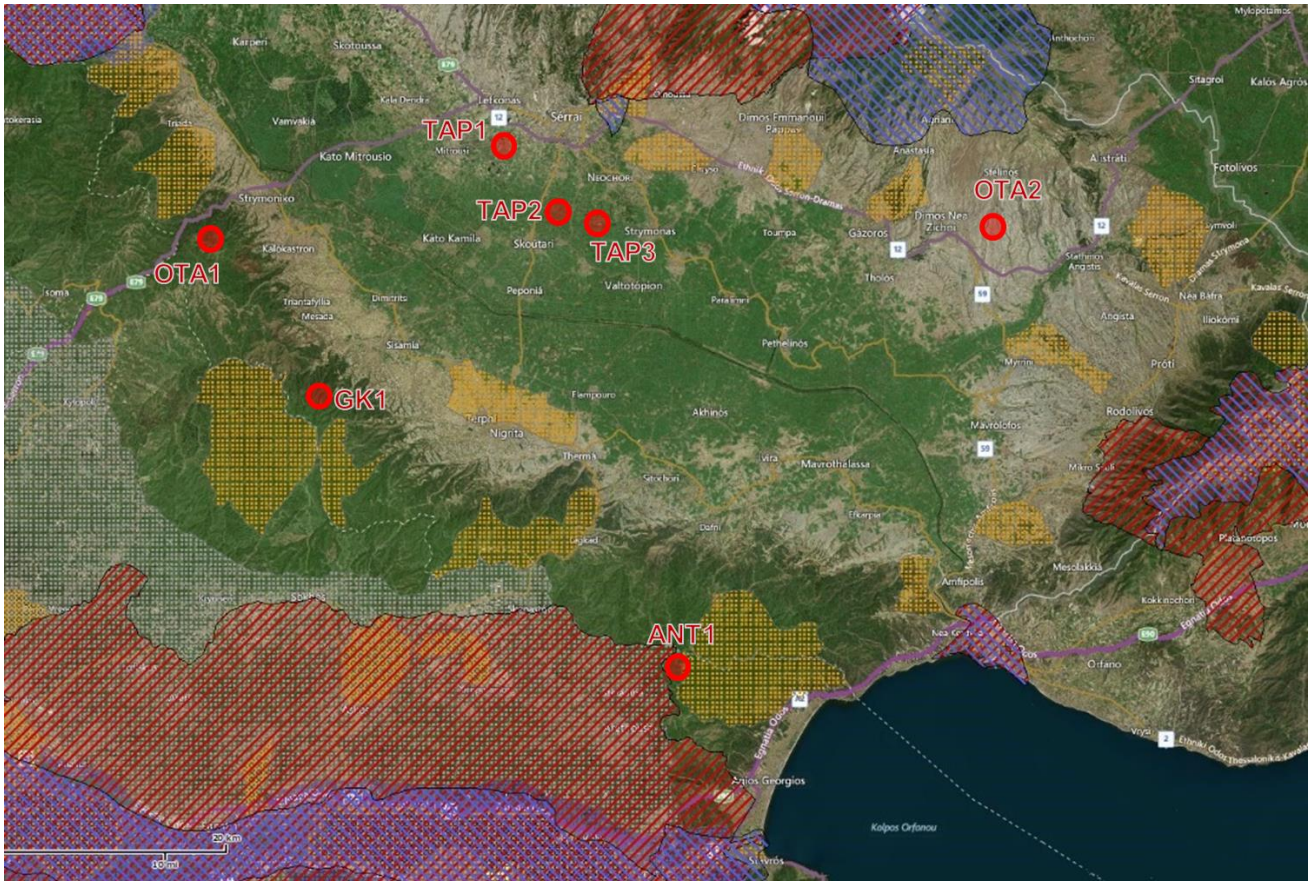
high expected noise level causing annoyance to the surrounding settlements. Moreover, the area is seismogenic and the impacts on nearby settlements, in the event of an accident will be extended. Thus there is a need for alternative locations to be proposed, evaluated and selected.

2. METHODOLOGY FOR SELECTING AND EVALUATING ALTERNATIVE LOCATIONS FOR THE GCS01 COMPRESSOR STATION

2.1 Selection of alternative locations for the Compressor Station GCS01

Two alternative locations for the Compressor Station GCS01 were proposed by the Serres Prefecture (locations OTA1 and OTA2), one by local groups (location ANT1) and one by the authors (location GK1). OTA1 is located 20 km west of the city of Serres and OTA2 25.5 km east. ANT1 is located 5.02 km northwest of Asprovalta on Kerdyllion Mountain, and GK1 10.22 km west of Nigrita on Mount Vertiskos. The alternative locations were carefully selected to be outside NATURA 2000 protected areas, as shown in Figure 2, where with red colour are marked Special Protection Areas (for bird protection) and with blue colour are marked Special Areas of Conservation and Sites of Community Importance [20]. In addition, these locations are away from residential settlements, in contrast to the TAP proposed locations. The evaluation of these alternative locations was a complex problem with several parameters. Hence, the Multicriteria Decision Analysis Method (MCDA) was selected as an appropriate methodology for their evaluation and ranking.

Figure 2. The three TAP proposed locations and the four alternative locations for the Compressor Station GCS01.



2.2 Evaluation of alternative locations for the Compressor Station GCS01

The Multicriteria Decision Analysis Method was performed by setting carefully selected criteria and alternatives. The factors ‘project development cost’, ‘aquifer pollution’, ‘soil pollution’, ‘air

pollution', 'noise and vibrations', 'accident risk', 'socio-psychological factors' and 'effect on local activities' were selected as criteria K_j. Each table row in Table 1 corresponds to one of the seven alternative GCS01 Compressor Station locations E_i. Subsequently, weights B_j for each criterion and rankings per criterion and alternative were set in a scale of zero to ten (0-10). The total rank AE_i for each alternative location is given by the Equation 1. The proposed locations by the TAP consortium, i.e. TAP1, TAP2 and TAP3, are physically close to each other, within a distance of less than 4 km, thus only one of them was evaluated since they have similar characteristics and it seems that TAP3 is the preferred one by TAP consortium.

$$AE_i=\Sigma(B_j*E_iK_j)\ ,\ \ i=[1\ldots7]\ ,\ j=[1\ldots8] \quad (1)$$

In Equation 1, E_iK_j is the ranking per criterion and alternative in a scale of zero to ten (0-10). Among the sums AE_i, the minimum one is selected as the best, as the weights are set higher for more negative impact. On this basis all the alternative locations were evaluated as shown in Table 1.

The weights of the different criteria were set by the authors taking into consideration, for each one, its nature and special characteristics according to the location. Other stakeholders may provide their own assessments since what is followed here is a transparent process. Hereafter the weights setting by the authors is explained and discussed.

Table 1. Multicriteria Decision Analysis Method for alternative locations of Compressor Station GCS01 evaluation.

Criterion		**K_1**	**K_2**	**K_3**	**K_4**	**K_5**	**K_6**	**K_7**	**K_8**	
Alternative		**Project development cost**	**Aquifer pollution**	**Soil pollution**	**Air pollution**	**Noise and vibrations**	**Accident risk**	**Socio-psychological factors**	**Impact on local activities**	**AE_i**
E_1	TAP1	3	7	7	5	6	9	7	8	376
E_2	TAP2	3	7	7	5	6	9	7	8	376
E_3	TAP3	3	7	7	5	6	9	7	8	376
E_4	OTA1	7	3	3	2	4	7	6	6	239
E_5	OTA2	4	4	4	3	4	7	6	7	266
E_6	ANT1	8	2	2	1	2	3	5	4	146
E_7	GK1	7	3	3	2	3	3	5	5	183
	Weight	1 **B_1**	8 **B_2**	9 **B_3**	7 **B_4**	8 **B_5**	9 **B_6**	6 **B_7**	6 **B_8**	

The first criterion was the 'Project development cost', which includes costs for land acquisition and construction. The weight of this criterion was estimated as the lowest one, taking into consideration the tremendous economic benefits, of the TAP consortium, from the TAP operation and also the permanent character of negative effects to the local communities and the Prefecture of Serres in general.

Weights for the three pollution criteria (Aquifer pollution, Soil pollution, Air pollution) were set high in a range from 9 to 7 and consequently the E_iK_j ranking was also high, in a range from 7 to 5, for the TAP selected areas in the plain of Serres, where the phenomenon of temperature inversion occurs causing the accumulation of pollutants with high negative effects on humans and also agricultural and animal production. Additionally, locations close to residential or other settlements were ranked with a high E_iK_j, in a range from 9 to 7, as far as it concerns the criteria of accident risk and impact on local activities. Locations ANT1 and GK1 are characterised by a high altitude, 560 m. and 524 m. respectively [21] and a distance from residential and other settlements. Hence, the E_iK_j rank ranges between 1 and 3, concerning the criteria of noise and pollution.

Objections against the three TAP proposed locations, include also the fact that aquifer is close to land surface, with a local minimum depth of 1 m, according to data provided by the Prefecture of Serres. In addition, the land value in the area of Skoutari and Neos Skopos is among the highest within the Serres Prefecture. These facts lead to low E_iK_j ranking in project development cost, equal to 3 points (the lower in this criterion) and the higher E_iK_j ranking in aquifer pollution, equal to 7 points.

The noise by the Compressor Station, as explained earlier, is going to be continuous and unceasing, and therefore acquires considerable weight as a criterion, set equal to 8. The location ANT1 is characterised by high altitude and safe distance from residential areas, which is more than 5 km away. However, there should be provision for sound effects in the natural environment (forest animals, insects etc.), that is why rating was set to 2. For GK1 location, which is more than 4.7 km away from the closest village, the rating was increased by one. The locations OTA1 and OTA2 are equally away from the nearest residential settlement, so their rank was set the same for both.

The criterion K7 includes the social and psychological factors and the reactions of local communities, related to the acceptance of the selected Compressor Station location by the locals. Therefore, the rank for each alternative is clearly dependant on the distance from settlements, facilities and agricultural areas.

The eighth criterion is the impact on local activities. These activities include premises and buildings, where people work, study or play sports. These facilities are: the Hippotherapy Centre located in Neos Skopos one of the two existing in Greece, the Serres Technological School, the Omonoia Athletic Park, the Greek Sugar Industry and the neighbouring industrial area, where every day hundreds of people work and move. In this criterion areas, such as workplaces or places where people accumulate, are considered. Hence, the locations on the Serres plain were ranked with the highest rating for this criterion (8 points). OTA2 was ranked with 7, OTA1 with 6, GK1 with 5 and ANT1 with 4 points as it is the most remote from settlements location. It should be mentioned that the criterion weight for the last two criteria was set equal to 6 as their significance is quite important, but lower than that of the criteria K2-K6, because there is the possibility of financing certain activities and premises to relocate in safer locations.

3. RESULTS AND DISCUSSION

The performing of a Multicriteria Decision Analysis yielded ANT1 location, on Kerdyllion Mountain, as the best solution, with an AE_i sum equal to 146 points and as second-ranked, in terms of appropriateness, GK1 location, on Mount Vertiskos, with an AE_i sum equal to 183 points. It is possible to construct the GCS01 Station at the GK1 location with a small deviation, of 11 km, compared to the already designed pipeline route by TAP AG.

The two above locations, having emerged as the optimal alternative solutions, do not seem to affect nearby settlements, in terms of accident risk and noise, as their distance from them is equal or more than 5 km. These locations are also characterised by a high altitude, potentially allowing for a better dispersion of air pollutants. They are also outside Natura 2000 protected areas. The TAP proposed locations are expressed by very high negative AE_i sum, thus they should be reconsidered.

Assuming that appropriate provisions are taken, air pollution could be probably reduced by using appropriate filters and increasing the height of chimneys significantly. Noise could be reduced by means of appropriate insulations. It seems that what could not be reduced is the probability of an accident, which is exacerbated by the fact that the area is seismogenic. Thus a change of the TAP selected location of GCS01 Station seems to be necessary.

Considering the whole consultation process with local communities, as performed by the TAP consortium, it seems that those affected should be given appropriate documentation and scientific support in clarifying their questions and concerns. The Environmental Impact Assessment Study is a very lengthy document, not easily comprehensible by non-scientists, thus probably a certain budget should be foreseen, in the cases of such high-impact projects, for local communities to conduct their own independent evaluation of the plans and the assessment of potential impacts.

4. CONCLUSIONS

In conclusion, it is clear that the country can benefit from the construction of the TAP pipeline, but it is important, in this planning phase, to try to avoid significant negative environmental impacts by selecting an alternative location for the GCS01 Compressor Station. This location should be in compliance both with the needs of the construction project and the requirements of the physical and built environment. In this paper, the performed Multicriteria Decision Analysis designated ANT1 location on Kerdyllion Mountain as the optimal solution, and GK1 location on Mount Vertiskos as the second best one, among these considered in the present study. The proposed by the TAP consortium locations were disqualified because of their proximity to a large number of villages and settlements, accident risks and other negative environmental impacts, which are assessed rather inadequately in the present TAP Environmental Impact Assessment Study.

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