

# Investigating the Effect on Productivity of a Geospatial Ticket Management System for Power Distribution Network Studies

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## ABSTRACT

Increasing productivity without jeopardizing the network's operation, consumers' experience, and the safety and integrity of procedures, is a major goal for all utilities. Scheduling of work has a direct impact on productivity, especially in the case of utilities that cover a wide geographical area using a limited number of employees. In the case of power utilities, however, scheduling has to consider, apart from the location of issues, the type and technical characteristics of each issue as well as its priority has to be considered in order to produce an optimum schedule. This paper focuses on the impact on productivity of a geospatial ticket management system considering the experience from such a system applied on network studies performed by HEDNO, the Greek Distribution Network Operator, in Patras Area. The term "network studies" is used to describe the study of all expansion and alteration works, ranging from a single Low Voltage (LV) pole installation to major Medium Voltage (MV) network rearrangements/expansion, and includes visits and measurements on the actual location as well as in-door calculations. In Patras Area, the local HEDNO division implemented in 2021-2022 a geospatial ticket managing system, based on available network data and custom Google Maps, aiming to increase its productivity by optimizing the scheduling process. Initial results published in February 2022, showed a significant productivity increase (up to 42%). However, the initial results considered a time span of only one month and thus could easily be misleading. This paper revisits the issue considering a larger time span (more than two years) that should provide more trustworthy results. It also briefly presents the latest updates and improvements made to the system. Results show that the increase in the number of studies and their predicted costs are similar to the initial results, with the increase in productivity being around 41%. In September 2022, HEDNO set the very ambitious goal of significantly increasing the overall production of network studies (more than double in terms of predicted costs) and the use of such a system can provide valuable help towards achieving this goal.

*Keywords*-power distribution network; ticket management system; geospatial; georeference; productivity;

## I. INTRODUCTION

Increasing productivity is a major concern for all organizations and businesses worldwide. However, an exact definition of the term or an algorithm to measure its increase or decrease is not easy to be provided as there are many factors and metrics that can be considered [1-3]. In the power sector, measuring overall productivity is a well-established field that considers many factors [4-6]. However, in the context of this paper, the term is used to describe simply the volume of produced work considering both the number of completed works and their predicted costs. The case study is the Network Engineering & Construction Section (NECS) of HEDNO's Patras Area, Greece (HEDNO being the Greek Electricity Distribution Network Operator). In 2021, NECS decided to adopt a geospatial ticket management system to increase its productivity through improved scheduling [7]. Initial results

published in February 2022 showed a significant increase in productivity ranging from 10% to 42% depending on the values considered each time [7]. However, a time span of only one month was considered as [7] focused mainly on presenting the system and initial one-month results were provided as an indication of potential improvement that the system could provide. It should be noted that, as explained in [7], this system was applied on both studies and actual construction works. Considering however that construction works are performed by outside contractors which are allowed to produce and follow their own schedule, in order to safely assess the impact of the system the current paper focuses on the results related to network studies as these were performed by HEDNO personnel only.

To assess the productivity of the network studies subsection one must consider both the number of conducted studies and the accumulated predicted costs, as neither one of these values,

when considered alone, can be fully representative of the actual workload and the productivity of the workforce. This is because simpler and smaller studies that can be conducted in less time generally result to lower predicted costs. On the other hand, larger and more complicated studies usually demand more time and result in rather higher predicted costs. This is especially the case when a study is related to underground lines [8-10]. Thus, if a large increase is documented in the number of studies but not in the accumulated predicted cost, this could be a hint that a bulk volume of simpler studies was conducted. On the other hand, if an increase is recorded in predicted costs but not in the actual number of studies, then this may be an indication that the same man-hours were reallocated from simpler studies to complicated studies or studies related to underground works.

In the context of a power distribution utility, especially one operating as HEDNO does in Greece, it is essential to note that neither aspect (number of studies and predicted costs) can be neglected. Further, the importance and priority of each task is not related to the complexity and cost of the related study. Factors such as safety and Guaranteed Services to Consumers [11] are the ones primarily to be considered. It has now been more than two years since the system has been incorporated in NECS's everyday work and the current manuscript aims to provide a report on the actual effect of this system on productivity considering both the number of studies and their accumulated predicted cost. It is important to note that there has not been any significant change related to other factors that could affect these values so it would be safe to attribute the changes to the use of the considered system.

## II. SET-UP

### A. Initial Set-up

The geographical area and considered network is presented in detail in [7]. The area covers over 1,500 km<sup>2</sup> and more than 200,000 consumers connected to over 3,000 MV/LV transformers. The basic characteristics of the geospatial ticketing system and several screenshots can also be found in [7]. The initial form of the ticketing system was developed following the following principles [7]:

- The system's main initial goal was to digitize and provide a geospatial representation of issues documented during the network's yearly inspection.
- Custom made Google Maps were used as a geospatial ticketing tool following some simple rules.
- A Point-Of-Interest (POI) was created in the position of each MV/LV transformer and indicated with the use of a small dot icon.
- Each LV ticket was attributed to the POI of the MV/LV transformer that fed the considered LV circuit, thus making this POI "active".
- Each MV ticket was attributed to a single POI, even if it was referred to a large line segment. The POI was to be placed roughly in the position of the issue.
- An active POI was to be indicated with icons (circles) of different color according to the priority of the issue described in the active ticket (low or high). The letters XT or MT were placed inside each icon to indicate LV or MV respectively.
- Multiple LV tickets could be attributed to the same LV POI. If the LV POI had an active high priority ticket, its icon would correspond to that ticket regardless of the number of low priority tickets that could also have been attributed to that particular LV POI.
- When a study was assigned, the corresponded POI icon's color was changed accordingly, and a small wrench sketch was also added to the icon.
- When there were no active tickets attributed to a POI, the POI was labelled "inactive" and this was indicated by a specific icon: a small dot for an inactive LV POI and a smaller (compared to active POI icons) green circle with the letters MT for an inactive MV POI.

A detailed table with all POI icons for the initial set-up can be found in [7]. Through everyday use, minor adjustments and updates were conducted, mainly related to the presentation of POIs. The basic changes are discussed in the next section.

### B. New Set-up

The initial scheme made no distinction between different type of LV tickets. This however meant that the user had to click on each LV POI to get a view of the ticket type, which was highly impractical. Thus, it was decided to create different icons for the basic different categories of issues usually described in tickets, as shown in Table I. The color and size of these POI icons vary to provide a visual aid related to the priority and importance of each category. In the new set-up, it was decided to include additional POIs and icons for consumer issues that could either be related to their connection to the network (connecting a new consumer or modifying an already active connection) or to construction works that create clearance issues. As explained in [7], according to Greek law the distribution network operator is allowed to construct and install network installations in private and public properties and no expropriation or easement is applied on the properties. Thus, property owners are still allowed to build on their property and the operator is expected to move the network accordingly in order to ensure clearance. This often creates a situation where a study is put on hold until detailed information is provided by the consumer and considered by the operator. Similar conditions apply for consumer connection issues as such studies may also be put on hold for a variety of reasons. Further, the operator is expected to expand the network accordingly when asked by local authorities, in order to provide poles that can support lights for public roads and areas. In that case, a rough initial study is performed on site in order to calculate the number of poles and the possible need of expanding the MV network. Then, the calculated cost is reported to local authorities which may choose to pay it or not (or even ask for a modified study). After the payment is made, a final detailed study has to be conducted.

Different icons have been created to depict all these different cases as shown in Table II. All these extra POIs are placed in the actual location of the issue for ease, and when the corresponding study is completed, the extra POIs are deleted, and the description and serial number of the issue/study is included in the attributes of the POI of the MV/LV transformer that feeds the considered circuit. A screenshot of the system is shown in Figure 1. Another improvement was adding additional information/attributes in POIs. As shown in Figure 2, POI attributes now include some additional boxes that are

used by users to write comments, information on previously cancelled or completed tickets, instructions etc. The approach of the initial system was that information regarding tickets would be depicted and then removed when the ticket was resolved. It soon became evident that these information should remain in the system in order to be visible and searchable at any time. This way, the user is able to identify duplicate issues or studies, a major factor that reduces productivity [7]. An instructions text was also added in each POI in order to help users being consistent when typing data.

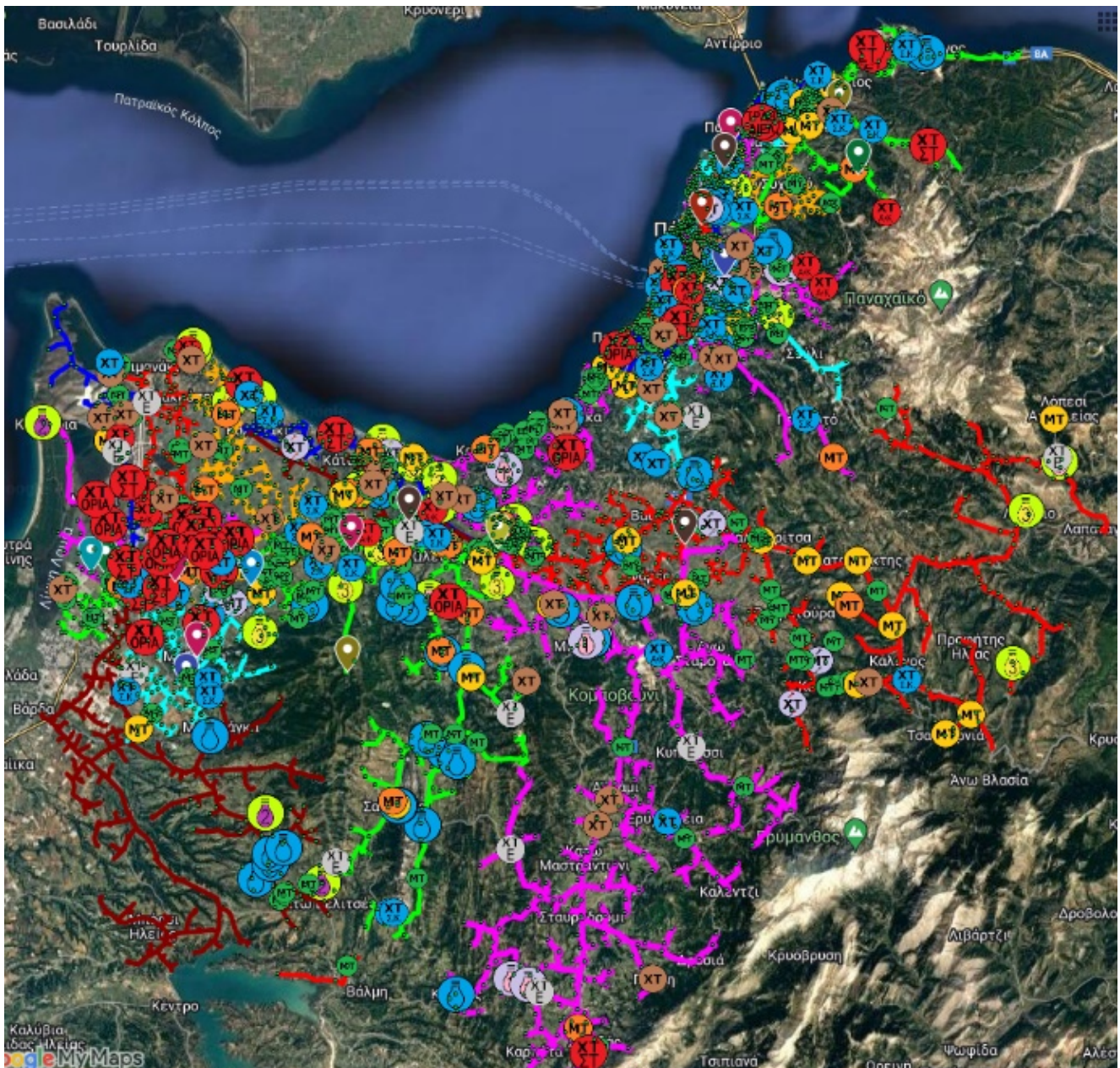


Fig. 1. A view of the Patras area study map with all POIs (screenshot from Google Maps, Map Data (c) 2023 TerraMetrics). The screenshot was taken shortly after the tickets from the 2023 yearly inspection had been received, which explains the large number of depicted POIs.



TABLE I. ACTIVE LV POI ICONS

	Transformer should be moved to a new location		Clearance issue
	Distribution box damaged and needs to be replaced		Conductors to be replaced by wire
	Distribution box needs to be replaced with a larger one		Transformer needs an additional crossarm
	Part of the network needs to be removed		Assigned
	Pole(s) needs to be replaced		Low priority (not specific)
	Tilted pole or guy-wire issue		High priority (not specific)

TABLE II. CONSUMER RELATED LV POI ICONS

	Consumer connection (new request)		Consumer connection (study assigned)
			Consumer connection (additional action required by consumer)
	Network should be moved due to construction works (new request)		Network should be moved due to construction works (study assigned)
			Network should be moved due to construction works (additional action required by consumer)
	Network expansion for public light (new request)		Network expansion for public light (initial study conducted and pending payment)
			Network expansion for public light (payment done, study pending)

III. RESULTS

The yearly work production of the network study subsection for the past three years is shown in Table III. The increase is separately depicted in Table IV. It should be noted that exporting the correct values from the archives is not an easy task as there is not a single software, universally used to track all issues. Instead, HEDNO uses a variety of software to track different works (e.g. RES related and not RES related studies) or to track different aspects of the same work (e.g. one software to track the dates related to a customer-related issue and another to track the payment and yet another to track metering issues etc). A brief list of software used around the time of HEDNO's separation from PPC can be found in [12] but the list has significantly increased since. Thus, a significant amount of workhours is actually necessary in order to acquire trustworthy data related to productivity.

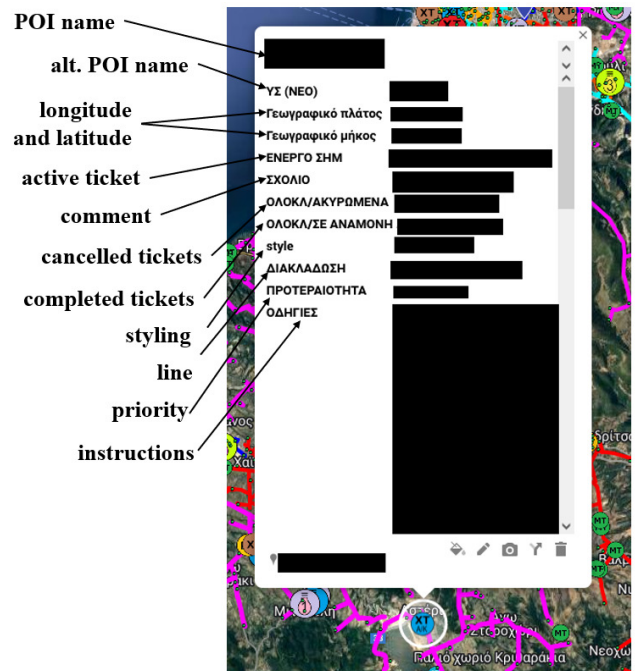


Fig. 2. The revised attributes box of POIs.

An easy way to bypass this problem is to consider the archives of the construction subsector within NECS [7]. These archives include the studies that are actually forwarded for construction each month and thus may exhibit some time-delay between the date of the study and the date that the study was forwarded for construction, but since all studies are forwarded for construction with a somewhat steady pace, this deviation can be considered negligible when trying to assess the overall trend. It should also be noted that all contracts between HEDNO and outside contractors consider the labor cost for each work and not the mixed cost, as most materials are provided by HEDNO. This also helps to better assess the productivity of the network studies subsection as it removes the cost of materials which would inflate the accumulated costs.

TABLE III. PRODUCTIVITY PER YEAR

Year	Number of studies	Predicted labor cost (mil. €)
2020	1308	2.15
2021	1471	2.9
2022	1842	3.04

TABLE IV. PRODUCTIVITY INCREASE

Time-span	Increase of number of studies	Increase of predicted labor cost (mil. €)
2020-2021	163 (12.46%)	0.75 (34.88%)
2021-2022	371 (25.22%)	0.14 (4.82%)
2020-2022	534 (40.82%)	0.89 (41.39%)

IV. DISCUSSION

Considering the data shown in Tables III and IV it is easy to observe that in the first year of application (2021) the increase was more evident on the predicted labor costs (34.88%) and not so much on the number of studies (12.46%).

This hints that larger and more difficult studies may have been conducted. However, as the system was fully incorporated in the second year, the increase was more evident on the number of studies (25.22%) and not so much on the predicted labor costs (4.82%). This hints that by fully utilizing the system and acquiring a wide view of the issues to be studied, it gradually became possible to schedule routes for the personnel that included a larger number of issues even though the related costs per issue were lower. As such issues (scattered and of low cost) are usually safety-related, this also hints that a major improvement in network's safety has been achieved. However, these results also show that there is a limit to the productivity increase that can be achieved by optimizing the personnel's schedule, and it is rather possible that this limit has been reached.

Overall, it is shown that the incorporation of the system has significantly increased productivity over these two years regardless of the value considered. As mentioned earlier, it is not easy to pin down and clearly define productivity, but the fact that both of the considered values are that similar is a strong indication that the produced workload has been increased by such a factor. Since no other factor has significantly changed over these two years, it is safe to assume that the incorporation of the geospatial ticket management system is largely (if not only) responsible for this increase.

It should be noted that in September 2022, HEDNO signed a new contract with construction contractors that significantly modified the terms (for a brief description of changes see [16]). A significant change was that vegetation management works, would now be included in the works studied and monitored by NECS (whereas it was previously studied and monitored by the Network Operation & Maintenance Section (NOMS) [7]). However, this change was mostly logistic as the actual studies were largely still conducted by NOMS personnel. However, these studies were now included in the sum of studies monitored by NECS and so had to manually removed from the dataset considered in this paper, in order for the data of 2022 to be equivalent to those of 2021. Further, the new contract demanded that the monthly predicted labor cost of studies assigned to the contractor had to be increased by a factor larger than two. This increase could not be achieved simply by vegetation management works. As discussed earlier, the productivity increase achieved through the use of the geospatial management system seems to have reached its limit, so NECS is expected to add additional studying personnel in 2023 to achieve the goals set by the new contract. This means that including data after 2022 will be misleading for judging the effect of the geospatial ticketing system on productivity except if significant manual work is conducted in order to isolate and remove the newly inserted factors in relation to previous years (i.e. vegetation management studies, additional personnel etc). Thus, it was decided to conclude and move forward with the publication of results for years 2021 and 2022. To avoid getting misleading results from the past, only data from 2020 was included in the analysis. This was done as it was easy to verify that the 2020 data was equivalent to 2021 and 2022 data, with all affecting factors being more or less identical. However, as one moved further in the past, it was increasingly possible that factors affecting the results would vary and thus comparing the

results from more years could be misleading. For example, personnel working with network studies had been moved from NECS some years prior to 2020 and vegetation management works were included in the dataset of certain years prior to 2020.

Geospatial systems have been used in a variety of power network applications (e.g. [14-19]), but the approach presented initially in [7] and further investigated in this work differs for two main reasons: that it is based on free to use web tools and that it incorporates a ticket management aspect. Thus, it is easy to be implemented by other utilities or organizations that wish to boost their productivity without increasing costs or significantly altering their infrastructure and mode of operation (providing that certain characteristics of their work is similar to the ones presented here i.e. they cover a wide geographic area and face a variety of issues).

## V. CONCLUSION

This paper focuses on the effect that a geospatial ticket management system had on the productivity of the network studies subsection of the Network Engineering & Construction Section (NECS) of HEDNO's Patras Area, Greece. The system and relative background has been thoroughly presented in [7] whereas the current work focuses on investigating the results on productivity after two years of operation. Some updates and improvements made on the system over the last two years are also briefly presented. Two different values were considered to measure productivity: the number of conducted studies and the accumulated predicted labor cost of these studies. This was done in order to acquire a better view on the actual effect of the system and to avoid misleading assumptions. Both these values exhibit a similar increase (40.82% and 41.39% respectively) over the past two years. Since, the other contributing factors (personnel, workhours etc) have remained largely unchanged over these years, it is strongly hinted that the system had a significant effect on the productivity of the subsection. Considering that the system is based on free to use software (mainly Google Maps) it is thus proposed that similar systems can be utilized to increase the productivity of any utility or organization that covers a wide geographical area and faces a variety of issues.

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