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Methodology for Optimization of Road Works Schedule According to Local Climatic Data

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Abstract**: *Road works, either from public or from private sector, are designed and constructed according to specific requirements that are commonly governed by national regulations. In Greece, "Road Design Guidelines Manual" and "Greek Technical Specifications" of the Hellenic Organization for Standardization or, in some cases, European Norms, stand for the framework road works are implemented. The common practice for projects design, consists of usual addressing of schedule followed and periods of year that work is suspended.***

Financial and time requirements, following this framework, usually do not take into account prevailing weather behavior on each work site. A methodology to optimize this procedure, according to local climatic conditions, is presented in this paper. The improved schedule is finally conducted by considering, in addition to the common practice, special local climatic data, following a step by step scheme, comprehensively explained in this study. Usual practice dictated by Greek specifications on the road works field, is enlightened. Reduction of these valuable resources requirements is the main purpose of the proposed methodology. Accordingly, a holistic approach considering apart from common project time management techniques, climatic uniqueness of each work location as well, is the quintessence of this paper.

Redistribution of working time-periods and re-arrangement of machinery equipment along with adequate personnel, based on climatic features of the location each road project takes place, is the crucial factor that boosts up productivity and releases resources that are unnecessarily assigned either to work or to be suspended in the frame of a typical timetable, main characteristic of which, is programming excluding winter months, as general rule. In this study, the frame, as for the schedule, considering the special climate features of each road project, is proposed accordingly.

Keywords**: *climatic data, expenses minimization, road works, schedule optimization, time resources.***

I. INTRODUCTION

Road authorities as well as private sector constructors have achieved, through last decades, continuously growing improvement in terms of speed and effectiveness during the phases of design and construction of both small and large-scale road projects. Technological knowledge and modern engineering equipment of high productivity are the most decisive factors contributing to this direction. Nevertheless, commonly used schedules include certain time periods of year with totally no activity due to potentially climatic phenomena of high possibility (rain, frost etc.), depending on localization of construction site. Additionally, programming of distinct operations leads to loss of time and consequently to time consuming projects that could be implemented with less time and financial resources. This is a usual observed case, due to unused information that could be gathered so as to optimize the project scheduling.

Gathering of climatic data that could help road authorities to minimize expenses and time, as well as to match their available resources to the right time periods in terms of favorable weather conditions each location presents, is the crucial issue this study examines.

II. METHODOLOGIES USED FOR SCHEDULE OPTIMIZATION (COMMON PRACTICES REVIEW)

The necessity for quick and economical completion of the technical works is becoming more and more urgent. Due to the complexity of the processes, many techniques and models have been developed in recent years, aimed at accelerating construction, while studying the critical factors for their successful implementation and consequently for successful and on-time completion of projects. Since now, the classical practices usually applied, are as follows:

1. Scheduling Optimization (optimal duration - lower cost) [18]:
- Partnering
- Critical Chain Project Management
- Acceleration / Duration Compression - Fast track

2. Schedule Optimization by Adding / Increasing Resources (Crashing)

A detailed review of the project scheduling can be found in many research studies [7], [8], [12-14], [17], [20]. As regards how Critical Path Management (CPM) has been used in the construction industry can be found in Galloway (2006) [3].

For the implementation of a project, it is important to consider other factors just as important as the resources required [1], [19] and special characteristics each project presents [15]. It is therefore important to have a limited time allocation of resources, so that they are available for the time period required and sufficient in number to complete the task. The resource allocation or allocation process determines the total number of resources required in each project time period, based on a project implementation schedule (Gantt chart).

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In combination with the above methodologies, in recent years, new innovative practices have also been gradually applied to the construction of technical projects such as the BIM (Building Information Modeling) application aimed at facilitating communication between participating members of the construction process, avoiding / correcting faults long before construction begins and ease of maintenance / repair [16].

None of the methodologies applied to date, take into account the climatic features of the wider area where the project is being constructed and this is the field in which the present study investigates, namely climatic data integration into the project timetable.

III. PROPOSED METHODOLOGY

This paper presents a comprehensive methodology for re-scheduling, taking into account - in addition to the classical practices applied - climatic data of the area. Firstly, the work schedule is modified by applying the aforementioned practices, and then, after processing historical climatic data (rainfall, temperatures), it is further optimized to reduce costs and speed up the completion of the project. The following flow chart depicts the proposed scheduling scheme (Fig. 1).

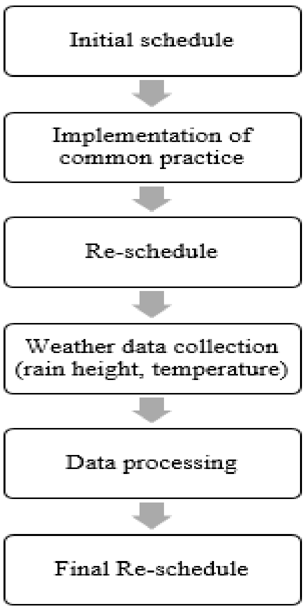


Fig. 1. Proposed scheduling flow chart

The above illustrated proposed methodology is analyzed as follows:

- Initial schedule:

The project's timetable, usually in the form of a Gantt chart. It is conducted by engineers that hierarchize tasks along with attributed personnel and machinery equipment. In the context of initial programming, winter season (December, January and February) is usually a non-active period for the construction phase.

- Implementation of common practice:

Acceleration / duration compression of tasks, increase of resources, according to common project management techniques.

- Re-schedule:

New improved project's schedule following the previous step.

- Weather data collection:

Historical rain heights and temperature data, collected from weather stations nearby the projects.

- Data processing:

The collected data are processed out of the specifications time periods dictated by high rainfall heights – high/low temperature levels, are marked accordingly.

- Final Re-schedule:

The aforementioned time periods are excluded from project's schedule working periods, while non-active periods from initial schedule are included if it is acceptable from climatic information derived from data processing. Subsequently, redistribution of tasks duration and time period takes place. Thus, the final schedule is set.

In order to make the proposed methodology more comprehensive, an implementation example is presented hereafter.

IV. GEOGRAPHICAL POSITIONING – SHORT PROJECT DESCRIPTION

The case study area is located at the Municipality of Larissa of the Prefecture of Larissa of the Region of Thessaly. The project under construction is located in an area within the urban plan of the city of Larissa, with altitudes ranging from +72 m to +75 m. In the present paper, the reconstruction of a Karamanlis Avenue (Old National Road "Athens – Thessaloniki") segment, is studied based on the proposed methodology. The segment extends from the intersection (I/S) of the "Volos" Road (K.P. 7+115) up to the intersection of "Agia" Road (K.P. 8+110), with a total length of 1.3 km.

In the following figures (Fig. 2 and 3), the segment (red line) and both intersections are indicated in the extract of the map sheet of the Hellenic Military Geographical Service [9] and in a Google Earth view, accordingly.

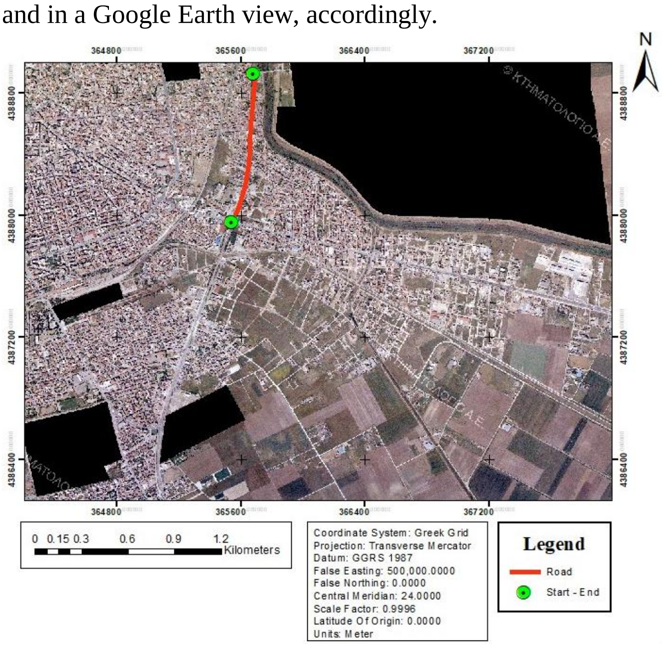


Fig. 2. Area extract from the HMGS's topographic map, "Larissa" leaf, scale 1:50,000 (the present figure has no specific scale)

Fig. 3. Satellite imaging of the road [21]

A. Project's Horizontal Alignment

As for the geometry of the artery, it is pointed out that the urban segment consists of two alignments, interposed between two horizontal radial curves R_1 = 1,400 m (between I/S "Volos" and I/S "Eretria"), R_2 = 7,600 m (I/S "Agias") and an adaptation curve with the existing infrastructure on the K.P. 8+280 radius R_3 = 2,000 m at the end of the alignment. These values are acceptable for the design speed of road V_e = 70 km/h (Category BIII - urban artery running through urban and suburban areas with basic connection function and constraints on the service of lane property) [11]. Road geometry allows for higher speeds that are prevented by three roundabouts and reduce of permissible speed limit to 50 km/h when passing through them.

The side roads that are located on either side of the artery along its entire length, contribute to comfortable, smooth and secure communication and service for passing activities (mixed commercial and residential use). These roads have a design speed of V_e = 40 km/h and have a collector road character with basic access function.

The vertical roads that contribute to the side roads have a local-service road character, except those forming the at-level intersections, which have the character of collecting roads. Their design speed is V_e = 30 km/h.

The following figure (Fig. 4) shows the general horizontal layout of the segment under study.

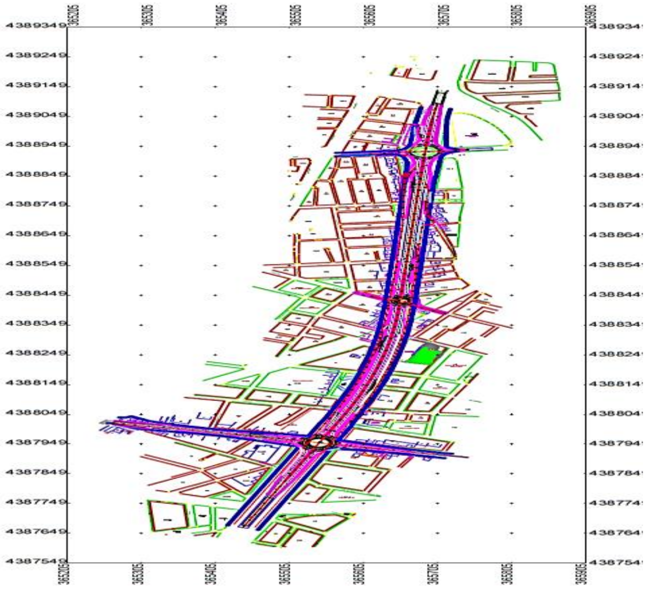


Fig. 4. General horizontal plan (no scale)

B. Operations Timetable

The project is proposed to be constructed in two phases due to its dominant role in inter-connection and transportation for the whole Prefecture of Larissa.

In the first phase it is proposed to be constructed both sideways and vertical roads and the connection to the existing road network.

In the second phase will be the proper marking and signing of the diversion of the existing old national road's traffic to the side roads and then the reconstruction of the old national road and its conversion into an urban artery.

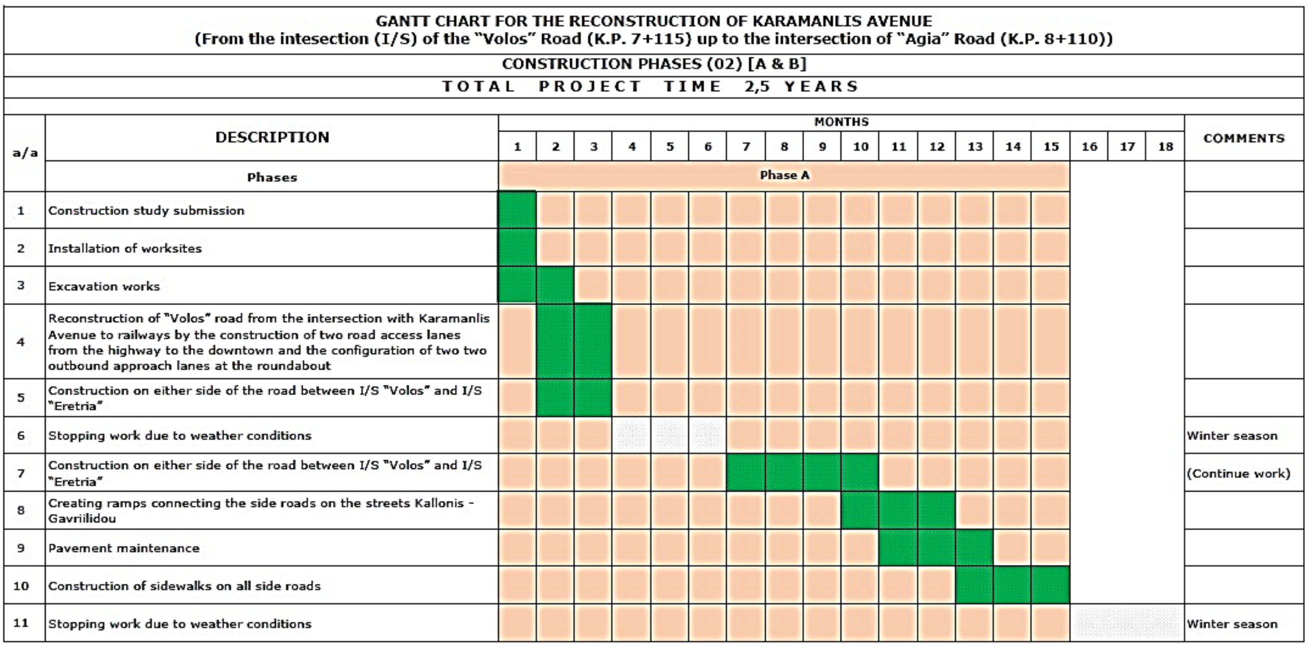
Particular attention should be paid during construction to the removal, re-installation and rehabilitation of the various public service networks (electricity, communications, water), which should be done with the least possible damage.

All of the above are described in more detail in the form of a Gantt schedule in the following graph (Fig. 5).

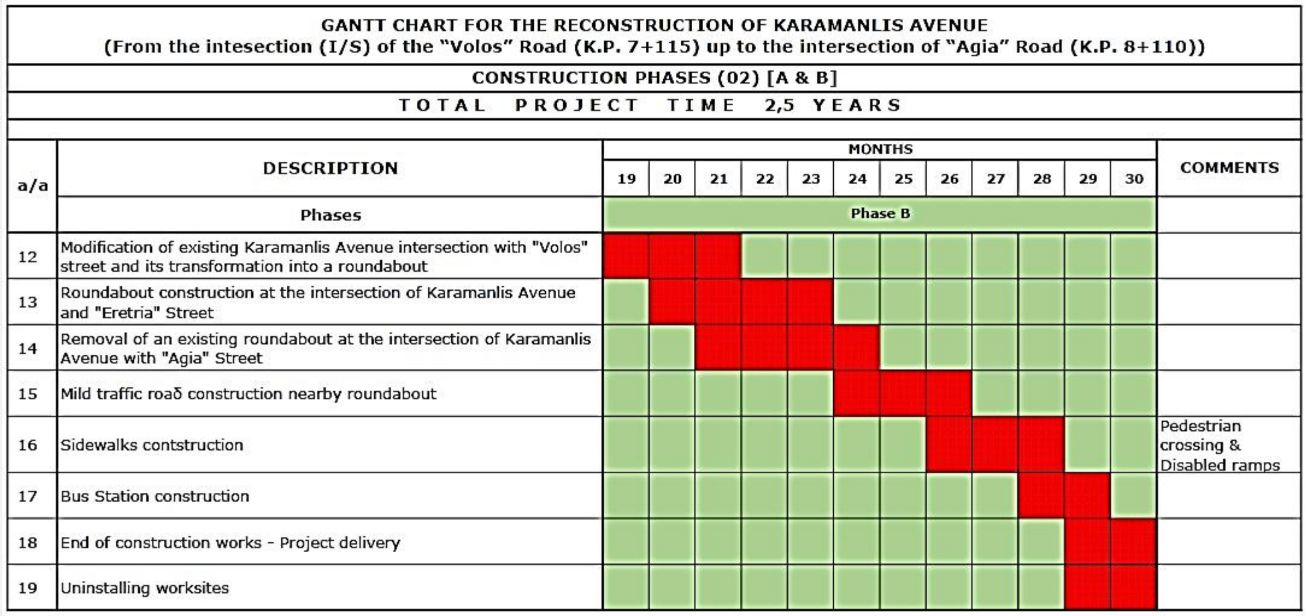
V. IMPLEMENTATION OF PROPOSED METHODOLOGY FOR TIMELINE IMPROVEMENT

A. Optimization of construction scheduling according to common practice

The way and the time of construction of the project is particularly important and essential for the good and trouble-free construction of the project. Initially, for technical reasons, the project is proposed to be constructed in periods of mild weather (autumn-spring) and not winter where the adverse conditions are not suitable for the construction of road works and technical works. Also, in the summer, where there is an increase in traffic volume on the road, it would be advisable most of the first Phase works to have been completed. In the figure below (Fig. 5), the schedule of the project is presented. The first month, namely September, is considered to be the month of the beginning of the project.



(a)



(b)

Fig. 5. Initial project schedule (a) Phase A, (b) Phase B

B. Modification of the project timetable according to local climatic data

Initially, classical methodologies were applied to reduce the length of the original timetable. A maximum reduction of 2.5 months was observed due to the re-arrangement of the works. Subsequently, a collection of available historical rainfall data (40 years) was obtained from an HMS Weather Station located near the road axis [10]. The corresponding temperature data were processed and evaluated at the same time. The graph below (Fig. 6) shows the average monthly prices for the past 40 years. The first month on the chart is the project's start month, that is September.

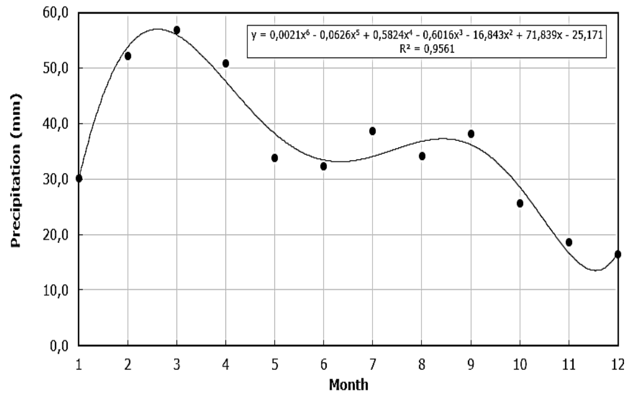


Fig. 6. Average monthly rainfall heights of historical data

The highest average rainfall values are observed in the autumn months (October - November), while they are rather high in the spring months. Therefore, the initial assessment of project implementation planning during the mild months (autumn - spring) is not absolutely correct. At the same time, it is noted that maximum rainfall values do not deter most construction phases of the project. In addition, according to Figure 7, the average temperatures range from 5°C to 28°C.

This range of temperatures does not necessitate stalling all works to be carried out, during the winter, but redesigning their scheduling to be implemented when the weather permits. It is noted that according to Technical Guidelines 1, 2 and 3 [4], [5], [6], the permissible range of work for concrete is 5°C-35°C. In addition, according to the ELOT (2009) [2] Technical Specification, only the surface course of asphalt layers should be implemented with a minimum air temperature of 10°C while for the binder course the minimum temperature is 4 °C and for the asphalt course 0°C.

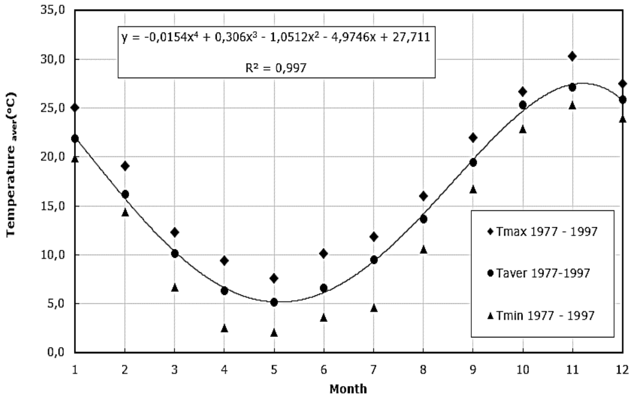
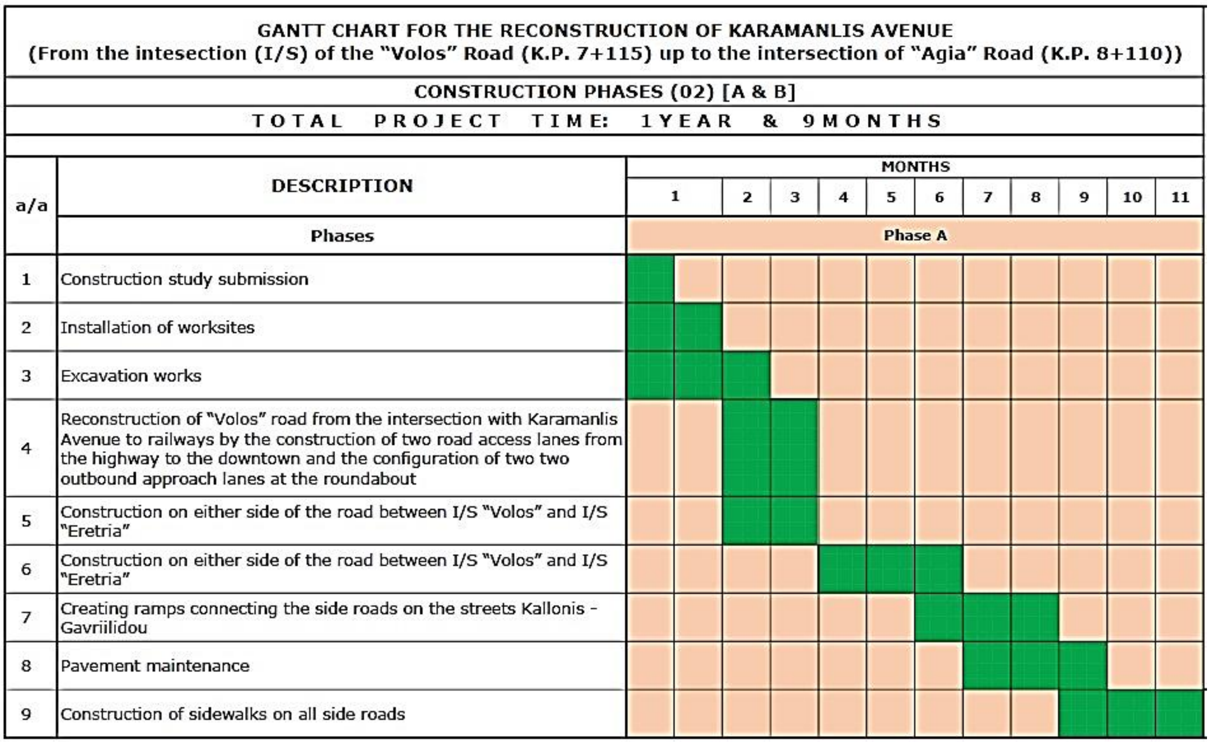
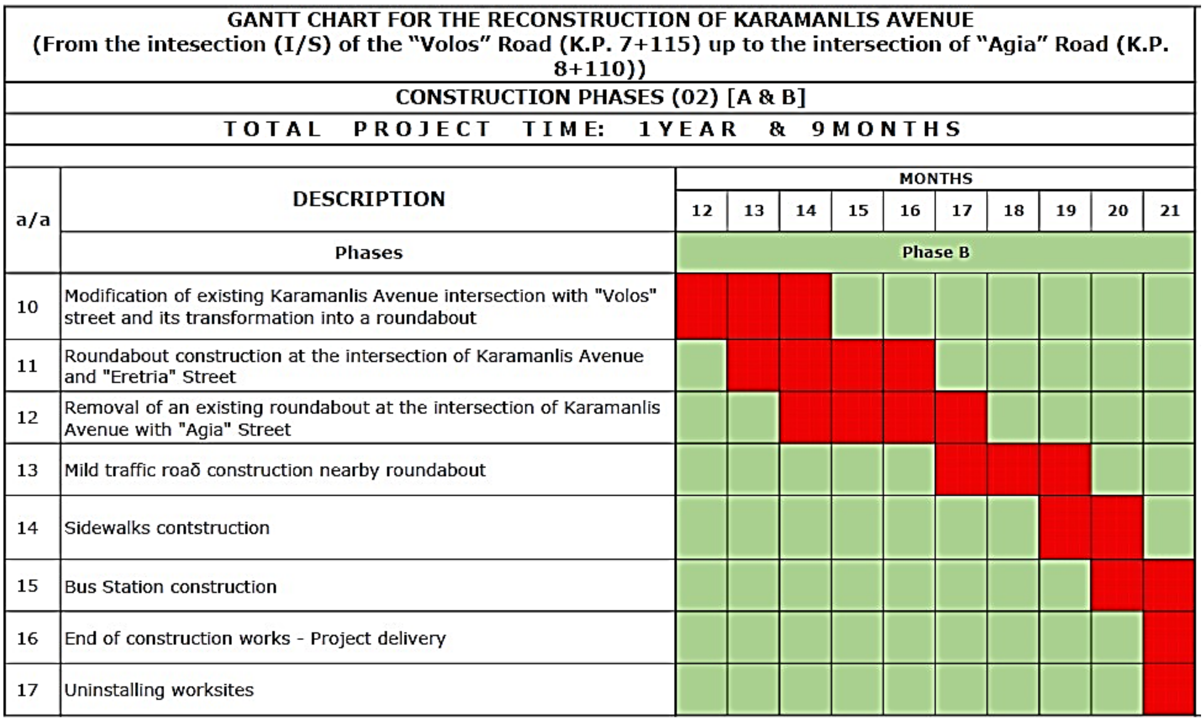


Fig. 7. Average monthly temperature values of historical data

Considering the above climatic data, the new project timetable is presented in the Figure 8 below.



(a)



(b)

Fig. 8. Modified project schedule (a) Phase A, (b) Phase B

VI. RESULTS / TIME GAIN BY IMPLEMENTING PROPOSED METHODOLOGY

By applying the proposed methodology, meaning that a step by step procedure for conducting final scheduling is implemented as presented in Fig. 1, it has been perceptible that the original timetable can be reduced to a total of nine months if no interruptions occur (Table I). In more detail, it appeared that during the implementation of the first phase of the project there could be a reduction of four months while in the implementation of the second phase five months. However, assuming that during the coldest month (January) works will be stopped, it appears that the initial timeframe will be reduced to seven months. This significant reduction in the duration of the project, namely 30% or 23.3% (in case of January shutdown) brings significant benefits to both contractors and competent authorities.

Table- I: Projects' time gains

Phase	Gained time including January in working-period (Months)		
	After common practices applied	After climatic data consideration	Total
A	1.0	3.0	4.0
B	1.5	3.5	5.0
A & B	**2.5**	**6.5**	**9.0**

VII. BENEFITS FOR ROAD AUTHORITIES – CONTRACTORS

Following the proposed methodology, road authorities and contractors, take advantage from special local climatic characteristics for increasing productivity, when strongly indicated by favorable weather conditions, while at the same time, avoid specific time periods contraindicated for operations. Thus, as ascertained above, the schedule of the project is minimized in terms of time, subsequently in terms of operation expenses and valuable resources are saved. Personnel and equipment are addressed according to the most productive time hierarchization, avoiding unnecessary loses from stalled equipment that could be used in other construction projects at the same time period.

In conclusion, it becomes clear that when designing project schedules, the climate parameters must be taken into account. It is easily perceptible, that re-scheduling with respect to local climatic data, boosts up work productivity, inasmuch, shutdown periods, dictated by adverse weather conditions are accordingly arranged. Machinery, equipment and human resources contribute to the works with minimum time-loss and tasks are hierarchized to the optimal sequence with respect to precipitation heights and temperature levels.

It should be noted, that relative research of local climate conditions has to be carried out for each project's timetable, given the fact that restrictions may significantly vary from location to location. Additionally, the more data collected, the highest thoroughness for re-scheduling project timetable and sequence of tasks.

Drawing on the very emboldening feedback from the implementation of the approach presented above, the authors are encouraged for future research potential, meaning assessment and valuation of gained costs by adopting the proposed methodology.

VIII. CONCLUSIONS

Classical methods for projects management minimize time requirements up to a specific extend. A step forward, stands for further improving project's timetable by taking into account special climate characteristics according to the location of the work site.

Based on the implementation of the proposed methodology, it has become easily perceptible that rescheduling projects' timetable with respect to local climate features, after the initial schedule, leads to significant gains in terms of time and, thus, to significantly reduced financial requirements. Moreover, the equipment and personnel are adequately attributed to the most suitable time periods, with respect to prevailing climatic periods of each work site.

By adopting the proposed methodology, the database regarding localized weather features, is dynamically growing. Thus, it can be very useful in other potentially future infrastructure projects in the wider area.

It is also worth mentioning of the usefulness the above methodology services as for the preparation of studies carried out by the Technical Services of Municipalities and Prefectures, since the extensive database it provides, could be combined with other time mitigation methods and stand for a useful tool that will significantly reduce construction time and cost of the project.

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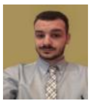

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