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Metodología contemporánea de Infraestructuras de Gestión de Proyectos, Prevención de controversias y Análisis de Retrasos
Contemporary Methodology for Infrastructure Project Management, Dispute Avoidance and Delay Analysis

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***Resumen*— Las causas de las interrupciones y retrasos en los proyectos de construcción de infraestructura son conocidos pero inevitables, y los métodos actuales de análisis son caros. En este trabajo se propone una metodología moderna para el mantenimiento de registros eficiente y transparente, y para la gestión eficaz de los proyectos y resolución de disputas más barato. Herramientas tecnológicas modernas (imágenes UAV, escaneo láser 3D, tecnologías BIM, visualización 3D, tecnología GNSS y RFID) se utilizan para proporcionar información útil e importante a un servidor de Sistema de Información Geográfica (GIS) central, que a su vez proporciona informes relacionados con las obras del proyecto.**

Palabras clave— Gestión de proyectos; Mantenimiento de registros; Prevención de litigios; Retraso; UAV; GIS; GNSS.

***Abstract*— The causes of disruption and delay to infrastructure construction projects are known but inevitable, and the current methods for delay analysis and dispute resolution are expensive and faced with suspiciousness. In this paper a contemporary methodology is proposed for efficient and transparent record keeping and sharing for effective project management, delay and dispute avoidance and cheaper dispute resolution. Modern technology tools (UAV images, Long-range 3D Laser scanning and BIM technologies can be used for data collection and 3D visual illustration of the milestone works progress; Time lapse camera images can provide visualisation of the daily progress of the works and indication of the conditions and presence of resources in any day; GNSS - Mobile technology can be used to pattern the machinery and human resources presence and motion on site; High resolution satellite images can give periodic images for the general progress of the works, RFID technology can be used for machinery and human resources monitoring and material quantities tracking and management) are utilized to provide important and useful information, both spatial and descriptive, to a Geographical Information System (GIS) central server, which in turn provides reports regarding milestone issues related to the project works.**

Index Terms— Project Management; Record Keeping; Dispute avoidance; Delay; UAV; GIS; GNSS.

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I. INTRODUCTION

THE PROCUREMENT OF INFRASTRUCTURE CONSTRUCTION PROJECTS is a complex process, not a mere event. Delays to the completion of the project are often caused by the large number of parties involved and the variation in the way these parties perceive important issues of the construction process. There are also other affecting factors, such as weather or miscalculations that cannot be foreseen. Furthermore, changes to the scope of the works or methods used are, in most occasions, unavoidable. Sometimes the ordinary mismanagement of the works from any party involved will inevitably cause delay in the contract completion date. Therefore, delay is an issue that affects the majority of infrastructure projects.

Considering the high costs involved in a construction project, none of the involved parties wish to be held responsible for, and bear the extra costs and expenses caused by delay(s). The justification of cause and effect of delay events often comprises a major dispute issue in construction cases. Concordantly, the delay analysis is forming a significant element in the resolution of construction disputes (SCL, 2006). In such cases, the quality and quantity of available records are of crucial importance, as well as the delay and disruption analysis itself (SCL, 2002). Evidently, a foremost objective of the professionals involved in the construction industry would be the avoidance of disputes. However, if one seeks to avoid disputes, he should seek ways to predict them, by taking the necessary actions to avoid delays (Fenn, 2002). Therefore, the efficient and systematic recording and the effective management of a construction project programme (Pickavance, 2010) may be essential elements of delay and dispute prediction and avoidance in order to have a successful project.

The methods used for record keeping are mainly the site diary, reports, correspondence, progress meetings´ minutes, drawings´ updates, variation instructions and site observations. The progress of works is usually presented and monitored by the contractor by updating the initial programme, which is in the form of Gantt charts (Fig.1). However, as-built programmes may contain uncertainties and inaccuracies. Consequently, mistrust regarding the subjectivity of the information may be generated to the side of the receivers, including courts (Gorse et al., 2005). Additionally, many interested parties that need to take important decisions related to the project progress may find it hard to visualise the progress of the works as described by the programme's Gantt presentation, and obtain an accurate position and location from text-based illustrations of a traditional schedule (Moon et al., 2014).

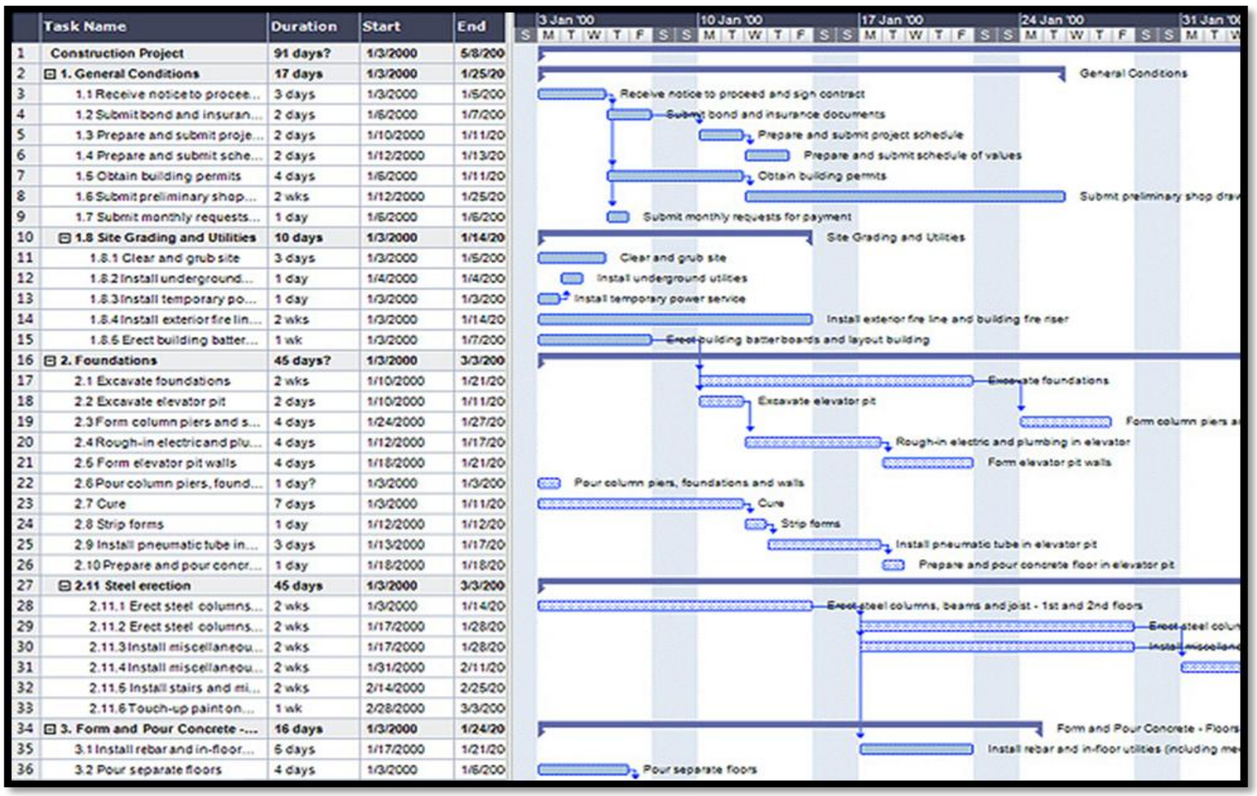

Fig. 1. A typical works programme in the form of a Gantt chart.

At this point, the question that arises is whether there are any other alternative options that could provide efficient and transparent record keeping, to increase the effectiveness in project management and decision making in order to avoid delay. Can there be a framework able to increase the transparency of the construction process, and works progress of a project to such a level that disputes will be avoided, or in the case there is a dispute, to have the actual facts presented in detail before the arbitrator or adjudicator and, thus, decrease the duration and cost of the resolution procedure?

This paper considers the potential of developing a contemporary methodology for efficient and transparent record keeping and sharing, to achieve more effective project management and decision making, delay and dispute avoidance, and cheaper dispute resolution procedures. The methodology presented utilizes modern technology tools to provide important and useful information, both spatial and descriptive, to a Geographical Information System (GIS)-based central server, which in turn will be able to provide reports regarding milestone issues related to the project works. The aim is to develop an innovative tool that will be able to provide:

- Efficient and transparent record keeping and sharing,
- Achievement of more effective project management and decision making,
- Delay and dispute avoidance, and
- Less expensive dispute resolution procedures.

II. Modern Technologies and Equipment

New technologies for the acquisition of spatial or visual information, initially developed for the military, science, business or other purposes, are gradually finding their way in the construction industry. Such tools can be of immense importance for many critical phases of the project management workflow, e.g. in monitoring construction works progress. The technologies considered in the proposed methodology are the following:

A. Unmanned Airborne Vehicles

Until recently, Unmanned Airborne Vehicles (UAV), Unmanned Aerial Systems (UAS) and Remotely Piloted Vehicles (RPV), were mostly developed and used for military applications. These systems are remotely-controlled aircrafts or helicopters. With the recent availability of accurate and low-cost Global Navigation Satellite System (GNSS) receivers, the possibility opened up to maintain a UAV system's position in a global reference system nearly everywhere in the world and in real-time (Siebert & Teizer, 2014).

Fig. 2. The Department’s UAV used for the data collection

UAVs have undergone significant advances in equipment capabilities and now have the capacity to acquire high-resolution imagery from different angles in a cost effective, efficient manner. By using Metric Photogrammetry and Structure for Motion techniques, metric 3D information can be extracted. Distances, angles, areas, volumes, elevations, object sizes, and object shape within overlapping images are some of the many characteristics that can be determined using photogrammetric techniques (Adams et al., 2010).

In the building industry, UAV techniques have been used in order to examine damages on buildings because of hurricane events, and monitor the progress of roads and bridges (Ezequiel et al., 2014). UAVs are also suitable for a wide range of applications, particular in land surveying, façade construction, archaeological, cultural heritage, environmental applications, monitoring of a rock slide, management of construction site safety (Theodoridou et al., 2000 : Eisenbeiß, 2009 : Irizarry et al., 2012). Images taken from UAVs have been used for the generation of 3D-model of existing buildings (Theodoridou et al., 2000 : Zischinsky et al., 2000 : Jizhou et al., 2004).

However, although several researchers have previously introduced UAV technology to civil engineering applications, and it indeed promises to provide more cost- and task-efficient ways to conventional approaches, its performance in the construction environment has yet to be scientifically explored and evaluated (Siebert & Teizer, 2014).

B. Terrestrial Laser Scanners

Laser scanning has been used in construction as a nonintrusive scanning technology for data retrieval (Tseng et al., 2002). A scanner seems to be feasible for use with a ground profile at a large construction site with a relatively demand for accuracy about less than 1cm@100m and for cost estimations to be made for interior renovation sites. Previous industrial applications were not suitable for data retrieval of large objects such as buildings until the recent development of long-range laser scanner (Shih & Wang 2004). Contrary to digital imaging, laser scanning actually acquires 3D data (point clouds), thus, despite their initial cost laser scanners present characteristics that are well adapted to project 3D status tracking, and thus can be used for progress tracking and dimensional quality control (Bosche, 2010). For this reason systems have been developed that use a 3D free-form shape recognition algorithm for automatically recognizing CAD objects in laser point clouds (Bosche, 2010 : Gordon et al., 2003).

C. Building Information Models (BIM)

The 3D imaging potential of the above tools is naturally interrelated with Building Information Models (BIM). BIM has been defined as a digital visual representation of all of a building’s physical characteristics and relevant information of its life cycle (Manning and Messner 2008), the parametric 3D computer-aided design (CAD) technologies in the architecture- engineering- construction industry (Taylor and Bernstein 2009), the process of creating and managing parametric digital models of a building during its lifecycle (Lee et al 2006), or a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle (Succar 2008). Despite of various definitions of BIM, BIM is broadly accepted only as an advanced technology in the industry (Zhang 2013) that can help architects, engineers, and constructors to visualize what is to be built in a simulated environment in order to identify any potential design, construction, or operational issues (Azhar 2011).

Various visual representations of a project's schedule and associated information combined with visual representations of the project in progress (Tserng et al 2014), can assist with tasks, such as record keeping and management, that can eventually assist in identifying effective construction strategies for managing a project's duration, and as evidence in dispute resolution procedures (Burr and Pickavance 2010).

The rising importance and use of BIM is evident in the fact that the UK government has decided that all major construction projects in the public sector must be working at Building Information Modelling (BIM) technology by 2016; by 2016 all centrally procured public construction projects in the UK will use BIM processes throughout. The drivers for the adoption of BIM as set out in the BIS BIM Strategy and the Government Construction Strategy are: (a) the reduction of the asset costs and achievement of greater operational efficiency, (b) the facilitation of greater efficiency and effectiveness of construction supply chains, and (c) the provision of assistance in the creation of a forward-thinking sector on which growth ambitions can based upon. According to the related paper of HM Government published in 2012, BIM is considered a "game changer" (HM Government, 2012). The use of BIM has also been applied in China's construction industry and the government has promoted the development of standards so that the related industrial chains in the construction industry could share the application of BIM. The Chinese Ministry of Science and Technology has included BIM in the Outline of the National Long-Term Science and Technology Development Plan (2006-2020) and has been defined as an important project; additionally the Ministry of Housing and Urban-Rural Construction revised the construction standards to develop five BIM related standards (Su H., 2013).

D. *Time lapse Photography*

Time-lapse photography is the use of photography to compress elapsed time in a still or moving image. In that way, it allows processes or phenomena that take place over a period of time to be evaluated at a more convenient pace or in a manner where the subtle changes that occur during the event are more easily observed (Malin).

Time-lapse photography has been used for many years in the fields of astronomy, biology and botanic studies to study various phenomena. In the recent years, the concept of time-lapse photography slowly started being used in engineering projects having as objective the creation of records with respect to time of a dynamic system placed at a particular, unchanging, physical location. (Abeid et al., 2002 : Abeid et al., 2003).

E. *Satellite Imaging*

Satellite images have been used in civil engineering and construction industry for the study of rural constructions with regard to their subsequent reuse (González et al., 2006), detection and monitoring of the land use and land use changes to provide accurate and timely information for planning and management (Deng J.S. et al., 2009), and for mapping and monitoring land-cover and land-use change (Rogan et al., 2004).

Satellite images can be used to some extent for the works progress monitoring of large-scale construction projects in a macro scale approach. However new satellite sensors with 25cm pixel resolution are expected to be launched and used by 2016, providing even higher spatial resolution satellite data to

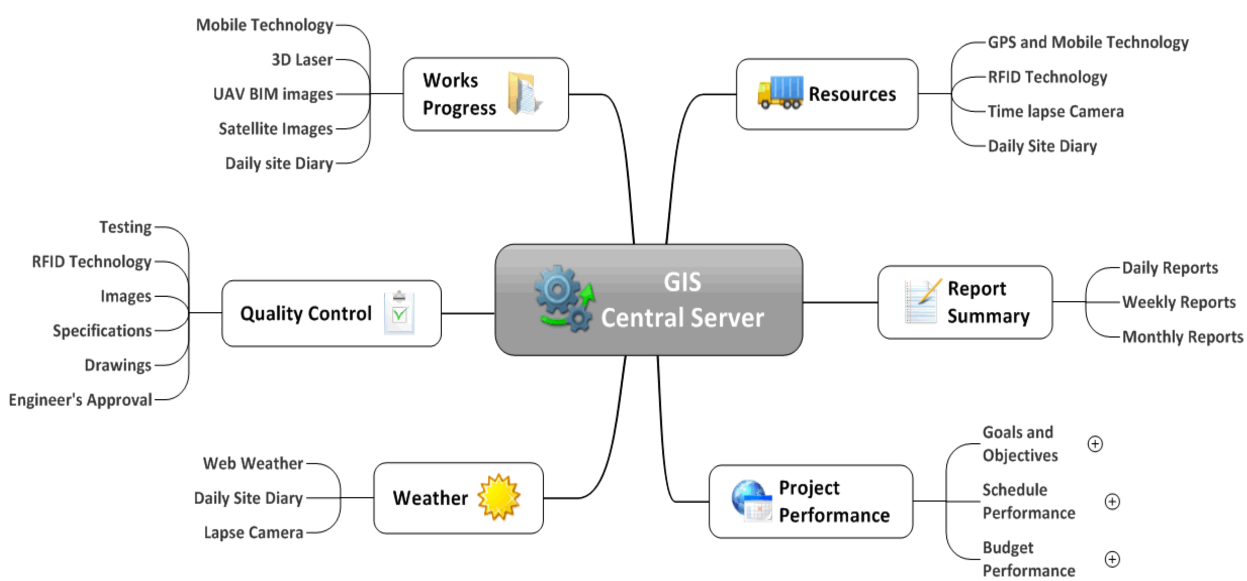

Fig. 3. The combined use of the modern technologies.

users.

F. *GNNS-Mobile Technology*

Global Navigation Satellite Systems (GNSS) tend to be a panacea in addressing positioning needs. Electronic devices such as smartphones, tablets or clothes integrate GNSS receivers to deliver position information in a wide area of applications ranging from safety of life (SoL) to leisure activities (Danezis & Gikas, 2012). The combination of GNNS and mobile technologies allows documentation of the movement trajectories of construction resources (personnel, equipment, and material).

Documenting the movement of construction equipment during construction projects is helpful in controlling and continuously improving construction operations. Specifically, documenting the trajectories of construction resources can allow the analysis of travel patterns of construction workers, assess equipment operators' work, labor activity, or study variability in construction processes (Vasenev et al., 2014).

III. COMBINED USE OF MODERN TECHNOLOGIES

The technologies presented above can be used in the construction industry individually for the efficient accomplishment of various individual tasks. This paper suggests that these technologies can be used in combination with each other for efficient and effective monitoring of a construction project's works.

For example UAV images, Long-range 3D Laser scanning and BIM technologies can be used for data collection and 3D visual illustration of the milestone works progress. Time lapse camera images can provide visualization of the daily progress of the works and indication of the conditions and presence of resources in any day. GNSS - Mobile technology can be used to pattern the machinery presence and motion on site - a similar approach can be used to document human resources presence. High resolution satellite images can provide periodic images for the general progress of the works. Also, although it has not been presented above, RFID technology can be used for machinery and human resources monitoring and material quantities tracking and management, and it must be explored.
In the proposed methodology, the information collected using the above technologies, as well as traditional site information, such as the daily site diary, drawing updates, test results etc., will be stored in a GIS-based server, or in this case a Construction Information System (CIS) server, that will be able to provide (as output) standard reports on various important issues related to the project management and works progress for early warning and dispute avoidance as shown in Fig. 3.

Furthermore, in the event of a dispute, valuable records and information will be available by the system in a most transparent fashion. The proposed system will assist in the preparation of a fair and detailed analysis of the delay effects, and their actual effect on the works progress, as well as the examination of an issued delay analysis.

Moreover, the proposed system will potentially act as a witness because of its nature, i.e. a large and important source of record information.

IV. PROPOSED METHODOLOGY

The proposed methodology will be designed around a contemporary tool, a GIS-based Server, as shown in Fig. 3 and Fig. 4 that will enable the collection of information from numerous sensors by means of modern technologies. The system will be able to generate reports on significant issues pertinent to the project. Specifically, the central server will be constantly accepting information from various sources and,

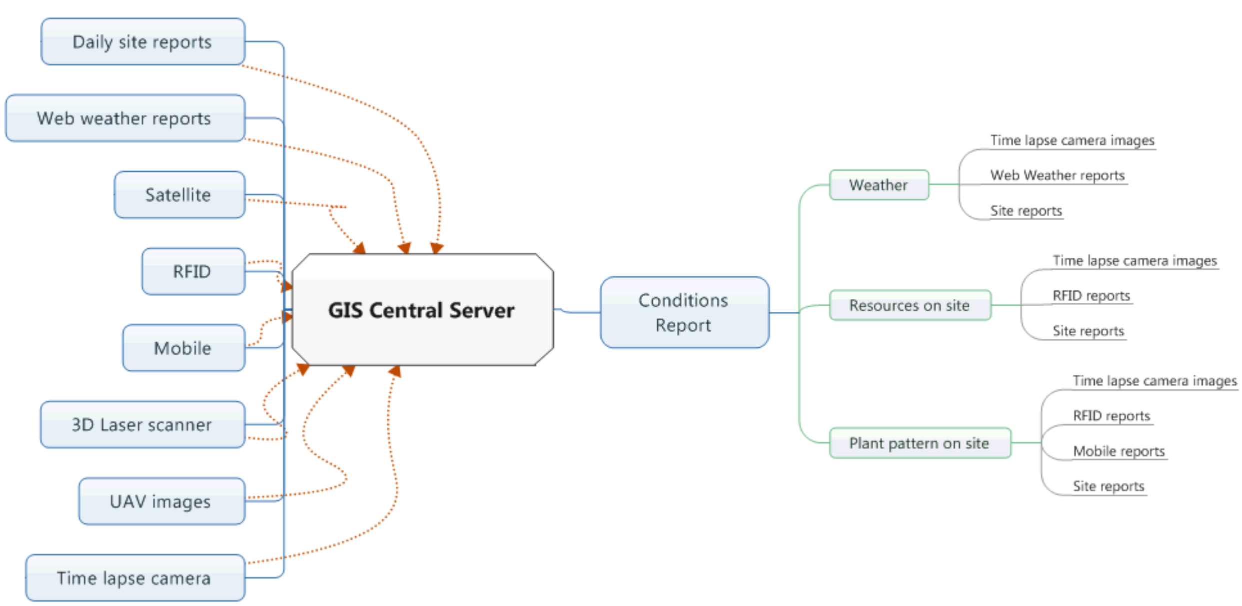

Fig. 4. The methodology of producing a typical conditions report.

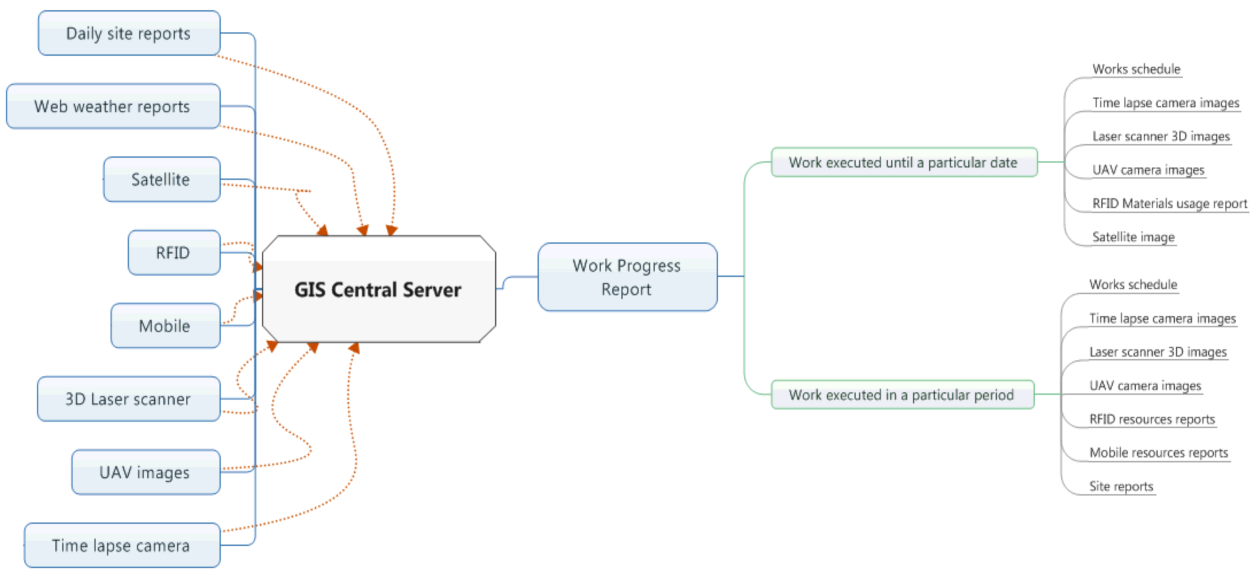

Fig. 5. The methodology of producing a typical works progress report.

depending on the required information, the relevant data will be used to provide the necessary report.

This technique can provide efficient, unbiased and transparent record collection and sharing the results to all interested parties within the framework of a project. This is a crucial element towards more effective project management and decision making for delay and dispute avoidance and, if needed, a more effective and cheaper dispute resolution procedure.

For example, in the case a conditions report is required for a particular day or period of time (Fig. 4) the central server may use the information provided by the time lapse camera (images), the collected weather reports, the site reports, the GNSS-based positions reports, and potentially RFID data in order to generate a report made of information about the weather, the resources on site and the plant and machinery pattern on site.

If a works progress report is required by a particular day or period of time (Fig. 5), the central server may use the information provided by the time lapse camera (images), the works schedule, the laser scanner 3D images, the UAV camera images, the RFID reports and the satellite images to provide as output a report consisted of information about the completed works until the requested date.

V. Resources and Legal Implications

For the development, implementation and evaluation of the proposed methodology the following technologies and systems will be assessed and used:

- UAV quadcopter with camera,
- digital photogrammetry, image processing,
- GNSS/GPS for the measurement of checkpoints,
- laser scanner,
- BIM software for 3D illustration,
- time-lapse camera for constant monitoring of the works progress and situation on site,
- mobile,
- RFID system,
- programming software,
- server to be used as the GIS server (the Construction Information System).

The use of the modern technologies mentioned, apart from the benefits and useful input they provide to the proposed methodology, they may involve legal implications since the collected data may contain sensitive information of parties that need to be protected. These legal implications must be explored.

VI. Conclusion

The causes of disruption and delay to infrastructure construction projects are known but inevitable, and the current methods for delay analysis and dispute resolution are expensive and faced with apprehension. In this paper, a contemporary methodology including the use of modern technologies has been proposed in order to achieve efficient and transparent record keeping and sharing for effective project management, delay and dispute avoidance and less expensive dispute resolution procedures.

The use of a contemporary methodology, which is comprised by a GIS Server will enable the collection of information from various sensors by means of modern technologies, and then generate reports regarding significant issues with regards to the project.

This technique can provide an efficient, unbiased and transparent record collection and sharing the results to all interested parties within the framework of a project. This is a crucial element towards more effective project management and decision making for delay and dispute avoidance and, if needed, a more effective and cheaper dispute resolution procedures.

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