Comparative Evaluation of Fleet Management Software in the Greek Construction Industry

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Abstract. Nowadays, construction companies are facing multiple difficulties on how properly and effectively manage their fleet of construction equipment. Fleet management (FM) is a feature that allows companies to avoid or minimize the risks associated with investing in equipment, efficiency, productivity, overall transportation costs, impartial compliance in legislation. FM can include a variety of functions such as equipment acquisition, maintenance, licensing, accident management, replacement, equipment tracking, health and safety management, and many others. Internationally, there have been developed many Fleet Management Software (FMS) that offer a company with several functionalities. In this research the functions of the most globally used FMS are analysed and evaluated according to their qualitative characteristics. A questionnaire was distributed among significant large construction companies and public construction institutions in Greece, in order to evaluate those characteristics. This allowed to identify their extent of use and to highlight the most important abilities that the users desire. Finally, these characteristics were ranked using the Relative Importance Weight (RIW). By this hierarchy process users’ needs are revealed, and further areas of software development are enlightened.

1. Introduction

Construction equipment FM constitutes a crucial, but also difficult part for the optimum and efficient operability for small, medium or large companies. Despite the fleet’s size, the necessity of having a fleet management software to leverage their productivity is more than imperative. FM is considered more as an administrative approach, which allows the enterprises to organize their equipment, with the ultimate goal to improve their efficiency, to reduce their operating cost and to comply with their country’s regulations and legislation. The advent of computing FMS are very popular among companies across the world, when coming to execute several tasks, such as long-distance transports and earthworks. In the case of enterprises with a large equipment fleet, FM becomes a challenge and a very complex procedure. It can also be explained as the processes that fleet managers utilize to manage all fleet and asset information, from acquisition through to disposal (from cradle to grave). This enables companies to reduce costs, improve efficiency and ensure compliance across an entire fleet operation.

FMS for construction equipment appeared during the ‘70s, and at that time the software offered only a few and very basic capabilities and functions. Since then, their continuous development reached a level where they are now able to manage the operability of hundreds or even thousands pieces of equipment. Some of their main abilities are focusing on: a. Equipment tracking, b. Monitoring operator’s behavior, c. Distance control, d. Main components and parts condition monitoring through sensors, e.
Damage and malfunction prevention, f. Live interaction between the supervisor and his operators, g. Preventive maintenance, h. Maintenance historical records, i. Manage spare parts reserves.

This study focuses on those unique characteristics of each FMS and offers a comparative analysis and software evaluation. Through a structured questionnaire, construction equipment experts, practitioners and Original Equipment Manufacturers (OEMs) were asked to evaluate each of their abilities, reflecting what the Greek construction industry demands. The analysis ranks the important characteristic according the users’ needs and discuss the areas of future development in FMS.

2. Literature Review

Jin et al. (2000) examined the fleet replacement problem of a profit-maximizing manager, by using an optimal control model that captures both utilization and replacement decisions. Their results indicate that the optimal replacement schedule and fleet size are influenced by utilization schedules, and vice versa. Thus, replacement and utilization strategies should be determined jointly.

Fan et al. (2006) highlighted the need for the equipment managers to shift their attention from operational-level decision-making to corporate-level strategic decision-making regarding equipment management, which is often a challenging job with the current equipment management system. They presented an equipment data warehouse and a prototype decision support system (DSS), which enables equipment managers to visually analyze the equipment fleet data from different perspectives and at various level of details.

Sener and Isley (2009) evaluated the use of the telematic technology in construction companies, determined its user acceptance, and assessed the differences it was making in FM. The difference made was to be assessed in terms of how this new technology had changed spatial equipment tracking, equipment utilization, equipment maintenance scheduling, operations analysis, job costing, and jobsite/project management related to construction equipment.

Dandwate (2015) distincts the three basic components of FM, which are Equipment assignment and optimization, Production monitoring, and Position and material monitoring, in order to analyze performance factors such as dump movement and haul road congestion to boost overall site productivity.

Gransberg (2015), in his final report for the Minnesota Department of Transportation, argues that Equipment Life-cycle Cost Analysis (LCCA) is typically used as one component of the equipment FM process and allows the fleet manager to make equipment repair, replacement, and retention decisions on the basis of a given piece of equipment’s economic life. He managed to develop a robust method that permits equipment fleet managers to maximize the cost effectiveness of the fleet by optimizing the overall lifecycle value of each piece in the fleet. The research compared output using actual data from current software to the output from the new stochastic LCCA method using equipment deterioration curves and probabilistic input variables for capital costs, fuel, and other operating costs to demonstrate enhanced ability to optimize FM decisions. His report was the foundation of this current study.

Said (2015) presented the development of novel telematics-based computational methodologies to support two major equipment FM tasks: fleet use assessment and equipment health monitoring. He used the telematics data sets of large equipment fleets (dozers, excavators, backhoes, and dump trucks) from two companies and he managed to verify and validate his research developments by providing insightful FM information.

Ametisyan and Skibniewski (2017) stressed the need of large-scale companies to monitor the exact allocation of their construction equipment, by utilizing geographical allocation methods. Further development of their research identified the need also to use management tools and metrics for a company’s equipment, to allow contractors to reduce their emissions, comply with local or federal regulations and to accurately assess the sustainability of their construction equipment fleet.

Vahdatikhaki et al. (2017) aimed to design a Multi-Agent System (MAS) architecture that combines Location based Guidance Systems (LGS) technology with advanced safety management methods to support the equipment operators on the construction site. A two-layer safety mechanism was proposed for the safety management in the MAS that enables proactive and reactive responses for the prevention of equipment-related collisions on the construction site. It was found that the proposed MAS structure
was able to effectively address the fleet-level coordination between earthwork equipment and potentially improve the safety of earthwork projects.

Lee et al. (2018) developed a GPS only-based fleet telematics system for heavy earthwork equipment which can analyze time log information of each equipment using GPS location data without utilizing any other on-board sensors and Controller Area Network (CAN) bus data. They also stated that fleet telematics aims to comprehensively control equipment groups through location tracking, maintenance control, and productivity monitoring of individual equipment based on real-time location and status transmitted to fleet control center from the equipment.

3. Methodology

3.1. Software Search

An initial research was conducted, to identify the existing FMS available in the global market. According to Dandwate (2015), FM can be defined by three basic components: Equipment assignment and optimization, Production monitoring, and Position and material monitoring. At its most basic level, FM is about monitoring equipment location for an entire fleet but beyond that, it also helps to ensure that machines are in the right location and that the amount and type of material they are moving is accurate. In modern projects, the customer's needs are demanding higher expectations. In order to consider a software as FMS, certain abilities should be provided to the demanding users. Table 2 presents the main characteristics of the examined FLSs.

3.2. Questionnaire Dissemination

From the Greek construction industry sector, there were 16 expert evaluators selected and asked to weight each FLS ability, in a scale of 1 to 5 (Table 1). These experts were selected according their experience (more than 20 years in the field) in large infrastructure projects either as construction managers of superintendents of construction equipment on sites.

Table 1. Evaluation Scale

|       | 1 | 2 | 3 | 4 | 5 |
|-------|---|---|---|---|---|
| Irrelevant | Less Important | Important | Very Important | Extremely Important |

3.3. Software Characteristics/Abilities

After conducting a holistic global market overview of the existing FMS, this study concludes to examine the main functionalities of 15 FMS with 30 different abilities, as depicted on Table 2.

Table 2. Fleet Management Software Main Characteristics

|                | Wialon | MyGeotab | Verizon Connect | GPSWOX | DIRECTOR Fleet Software (Teletrac Navman) | FleetLocate | Trackmatic | Fleet Complete | Fleet Commander | FleetFocus | FleetWave | Go Fleet GPS Tracker | ManagerPlus | Fleet Maintenance Pro | Flexio |
|----------------|--------|----------|-----------------|--------|-------------------------------------------|-------------|-----------|---------------|-----------------|------------|----------|----------------------|-------------|----------------------|--------|
| Equipment Cost Tracking | X      | X        | X               | X      | X                                         | X           | X         | X             | X               | X          | X        | X                    | X           | X                    | X       |
| Customizable          | X      | X        | X               | X      | X                                         | X           | X         | X             | X               | X          | X        | X                    | X           | X                    | X       |
| Fuel Management        | X      | X        | X               | X      | X                                         | X           | X         | X             | X               | X          | X        | X                    | X           | X                    | X       |
| Risk Management        | X      | X        | X               | X      | X                                         | X           | X         | X             | X               | X          | X        | X                    | X           | X                    | X       |
| Parts Inventory Management | X    | X        | X               | X      | X                                         | X           | X         | X             | X               | X          | X        | X                    | X           | X                    | X       |
| Equipment Log          | X      | X        | X               | X      | X                                         | X           | X         | X             | X               | X          | X        | X                    | X           | X                    | X       |
| Maintenance History    | X      | X        | X               | X      | X                                         | X           | X         | X             | X               | X          | X        | X                    | X           | X                    | X       |
| Tire Management        | X      | X        | X               | X      | X                                         | X           | X         | X             | X               | X          | X        | X                    | X           | X                    | X       |
| GPS Tracking           | X      | X        | X               | X      | X                                         | X           | X         | X             | X               | X          | X        | X                    | X           | X                    | X       |
Equipment cost tracking refers to stay on budget, on time and on track. The construction industry is transforming with the ability to monitor costs related to materials, labor and equipment usage automatically and from anywhere with sensor-driven data taken directly from the field. Using this data, FM software provides businesses the insights to predict and overcome project delays and communicate with customers before they become unhappy. To make FMS more attractive, it should be also customizable, meaning to enable users to customize features for their organization by integrating rules feature that is configured and ready for use with a simple selection. Fuel Management is related to any mode of transportation, involves the maintenance, control & monitor over the storage and consumption of fuel. Effective Fuel Management ensures the best utilization of resources and allows to reduce costs to a large extent.

According to Sener and Iseley (2009), construction equipment FM should allow companies to remove or minimize the risks associated with equipment investments, improving efficiency, productivity and reducing their overall ownership costs through what it enables equipment owners to do. Furthermore, according to the American Association of International Certified Professional Accountants (AICPA), for the overall success of any business, it’s in each company’s best interest to invest in optimized spare parts inventory management, by following nine simple rules: a. Choose a Method for Labeling Critical Components, b. Balance Inventory Volume With Sawtooth Diagrams, c. Keep Your Bill of Materials up to Date, d. Calculate Optimal Economic Order Quantity, e. Develop a Standard Work Order Process, f. Focus on Inventory Control During Employee Training, g. Perform Cycle Counts on a Regular Basis, h. Make Spare Parts Easily Accessible and i. Invest in a Quality Computerized Maintenance Management System (CMMS).

Equipment Maintenance Logs/Records are recorded histories on all the actions that have been taken on each equipment. Keeping track of the equipment’s condition helps keep the fleet at optimum working condition and minimizes the risk of unscheduled downtime or the equipment’s unavailability. The tire management system is a specialized system that monitors and helps to maintain all the tires. It can track the tires in every step until the time of scrapping. It ensures that the tire is repaired, changed, and checked to increase its workspan. A GPS tracking system includes asset tracking devices combined with an asset tracking platform, allowing to gain complete asset visibility and control and maximize asset utilization. The mobile application refers to the ability of having the full potential of FM through a mobile phone application. Network Support, in a broad sense, has to do with everything that keeps the organization's computer network running, productive, and up-to-date. It assures that all devices are healthy, and that hardware, software, and personal devices are compatible and working. The import and export of data is
the automated or semi-automated input and output of data sets between different software applications. True exports of data often contain data in raw formats otherwise unreadable to end-users without the user interface that was designed to render it.

Automated emails are carefully planned emails to be sent to subscribers at specific time intervals or as a response to the actions of users on a particular website. These emails can be sent individually or as part of a drip email campaign. Route Tracking File is the ability to store the executed equipment routes in a specific file system, for further exploitation. Maintenance management, when done properly, keeps assets in optimum operating condition. Less disruption in production or service leads to efficient operations, increases quality, and improves productivity. In addition, maintenance management lowers operational costs, protects the organization from liability, and improves environmental and personal safety. Inspection Management refers to inspect, collect, analyze, diagnose and monitor equipment. When combined with other information, like machine history and use, offers the ability to suggest repairs and maintenance for optimal safety and performance.

Equipment Life-cycle Cost Analysis (LCCA) is typically used as one component of the equipment FM process and allows the fleet manager to make equipment repair, replacement, and retention decisions on the basis of a given piece of equipment’s economic life (Gransberg 2015). To be effective, an accident or incident report should be timely, specific and concise. It should avoid vague or easily misinterpreted language and phrases that may cause confusion and instead keep things on point. Preventive maintenance (PM) is the regular and routine maintenance of equipment and assets in order to keep them running and prevent any costly unplanned downtime from unexpected equipment failure. A successful maintenance strategy requires planning and scheduling maintenance of equipment before a problem occurs.

Dispatch management improves scheduling and dispatching efficiency by avoiding downtime and delays, reducing unnecessary rentals, and automating routine tasks. Routing includes routes planning, create a series of stops or waypoints where vehicles are expected to stop to provide a service or make a delivery or pickup. TripLog is a trusted enterprise class vehicle mileage tracking and FM solution that provides easy to use mobile and web software as a service to simplify compliance, bring transparency and reduce employees time related to business expense reporting.

Real-time locating systems (RTLS), also known as real-time tracking systems, are used to automatically identify and track the location of objects or people in real time. Implementing a driver or operator management system allows to get a comprehensive look at the drivers or the operators, their productivity and the overall assets safety. A driver/operator management system can automatically upload vital information for the equipment fleet, such as fuel usage and telematics data. Alert notification is machine-to-person communication that is important or time sensitive. An alert may be a calendar reminder or a notification of a new message. The equipment status is the ability to transmit and record all the vital information coming from the equipment’s current condition. Repair tracking means the specific ability to monitor the equipment’s repairing condition. Warranty tracking is a specially designed for automating warranty claim process, which reduces the time consumed in processing the claims, by offering cross-browser compatibility as well as a responsive design.

3.4. FMS Characteristics/Abilities Evaluation
Table 9 presents the total weighting given for each FLS ability, where the response number of answers is represented, for each FMS ability. The related percentage reflects the desire rate of each ability.

3.5. FMS Overall Evaluation
Based on the questionnaire results, the use of the Relative Importance Weight (RIW) factor introduces the ranking for each software’s qualitative characteristic, as on Table 3, by applying Eq. 1 (Doloi, 2013).
\[ RIW = \frac{\sum_{i=1}^{5} a_i n_i}{\sum_{j=1}^{N} x_j} \cdot 100 \]  

(1)

where: \( x_j \) = the sum of the jth factor; 
\( j = \) the abilities 1, 2, 3, 4, . . . . . N; 
\( N = \) total number of abilities (30); 
\( a_i = \) constant expressing the weight given to the ith response: \( i = 1, 2, 3, 4, 5 \) 
\( n_i = \) the variable expressing the frequency of the ith response

for a response of ‘extremely important’: \( a_1 = 5 \) 
for a response of ‘irrelevant’: \( a_5 = 1 \) 
accordingly, \( n_1 = \) frequency of ‘extremely important’ response 
and \( n_5 = \) frequency of ‘irrelevant’ response

The summary of each ability’s RIW for every FMS provides the total software’s score. Table 4 demonstrates those aggregated results.

| RANK | CHARACTERISTIC          | RIW | RANK | CHARACTERISTIC          | RIW | RANK | CHARACTERISTIC          | RIW |
|------|-------------------------|-----|------|-------------------------|-----|------|-------------------------|-----|
| 1    | Equipment Status        | 3,76| 9    | Real Time Tracking      | 3,39| 21   | Tire Management         | 3,23|
| 2    | Work Order Management   | 3,71| 9    | Maintenance History     | 3,39| 21   | Repair Tracking         | 3,23|
| 3    | Maintenance Management  | 3,61| 9    | Preventive Maintenance  | 3,39| 21   | Life-Cycle Cost         | 3,23|
| 3    | Risk Management         | 3,61| 9    | Network Support         | 3,39| 24   | Inspection Management  | 3,18|
| 5    | Incident Reporting      | 3,55| 15   | GPS Tracking            | 3,34| 24   | Equipment Cost Tracking | 3,18|
| 5    | Accident Reports        | 3,55| 15   | Alerts/ Notifications   | 3,34| 26   | Dispatch Management     | 3,13|
| 7    | Fuel Management         | 3,45| 15   | Trip Logs               | 3,34| 27   | Warranty Tracking       | 3,08|
| 7    | Data Import/Export      | 3,45| 18   | Parts Inventory Management | 3,29| 28   | Driver Management       | 3,02|
| 9    | Mileage Tracking        | 3,39| 18   | Equipment Log           | 3,29| 28   | Customizable            | 3,02|
| 9    | Routing                 | 3,39| 18   | Mobile Application      | 3,29| 30   | Auto Email              | 2,76|

Table 4. FML Aggregated Results

| FMS                  | Score |
|----------------------|-------|
| Wialon               | 77,28 |
| MyGeotab             | 83,32 |
| Verizon Connect      | 69,91 |
| Telxon               | 80,36 |
| GPSWOX               | 66,64 |
| DIRECTOR (Telephone) | 69,96 |
| FleetWave            | 80,37 |
| FleetComplete        | 80,47 |
| FleetFocus           | 83,22 |
| FleetManager         | 80,42 |
| FleetWave            | 79,89 |
| FleetPlus            | 70,18 |
| FleetPro             | 57,68 |
| FleetPlusPro         | 60,33 |
| FleetPro             | 66,47 |

4. Findings and Recommendations
The results from Table 5 are representing the percentage evaluation of all the existing software abilities, where network support (68.75%), parts inventory management (56.25%) and maintenance management (56.25%) considered as the most precious. These rankings are demonstrating the evaluator’s concerns
and sensitivity on maintenance issues, recognizing the important role of maintenance regarding equipment’s productivity and efficiency.

According to Table 3, most of the evaluators consider that the Auto Email ability is of less importance (2,76), while other characteristics are demonstrating higher importance weighting, like the equipment status (3,76), work order management (3,71) and maintenance management (3,61). Once again, monitoring the maintenance status and the equipment’s constant working condition reveals to be of high priority for fleet managers.

Finally, the aggregated results of the above evaluation highlighted MyGeolab as the most promising and comprehensive software for FM, with a total score of 83,32/100. The worst FMS, according to the evaluators needs was Fleet Maintenance Pro, with a total score of 66,47/100, a fact that could be taken into consideration from the software developing company.

Although all the evaluators recognize the importance of utilizing this type of software, as a management multiplier that leverages each project’s efficiency, they stated that they are not using any FMS for their projects. Two reasons supported their choice: a. They heavily rely on field superintendents experience and project managers rather than new technology, and b. construction industry is very reluctant to the adoption of new technology in construction processes and their resources (i.e. equipment).

5. Conclusion and Future Research

This study aims to comparatively highlight the FMS features internationally and through a structured survey in the Greek construction industry to explore the user’s needs and recommend on future development in the field. Monitoring the maintenance status and the equipment’s constant working condition reveals to be of high priority among Greek fleet managers. Although, there is a common consensus that FMS are necessary, their use is limited. They seem to incorporate a strategy of “operate to failure” rather than “fixed time-based maintenance” or “condition-based maintenance” (Kannan, 2011) coupled with a general reluctance of construction industry to follow new technology. The future in FMS should be able to retrieve information gathered by sensors concerning equipment’s condition, combined with other specially designed sensors for operating data in order to be able to: a. offer a smart real-time construction equipment monitoring system and b. a smart prescriptive maintenance system, for boosting productivity and investment return of construction equipment assets.

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Table 5. Qualitative Evaluation of the FMS Abilities

| Ability                        | Irrelevant (1) | Percentage | Important (2) | Very Important (3) | Extremely Important (4) | Total |
|--------------------------------|----------------|------------|---------------|--------------------|-------------------------|-------|
| 1 Dispatch Management          | 6.25%          | 6.25%      | 18.75%        | 50.00%             | 18.75%                  | 16    |
| 2 Fuel Management              | 6.25%          | 0.00%      | 18.75%        | 31.25%             | 43.75%                  | 16    |
| 3 Incident Reporting           | 0.00%          | 6.25%      | 18.75%        | 25.00%             | 50.00%                  | 16    |
| 4 Parts Inventory Management   | 6.25%          | 3.00%      | 18.75%        | 31.25%             | 43.75%                  | 16    |
| 5 Equipment Log                | 6.25%          | 3.00%      | 18.75%        | 31.25%             | 43.75%                  | 16    |
| 6 Mileage Tracking             | 0.00%          | 2.00%      | 12.50%        | 37.50%             | 37.50%                  | 16    |
| 7 Routing                      | 0.00%          | 2.00%      | 12.50%        | 37.50%             | 37.50%                  | 16    |
| 8 Driver Management            | 0.00%          | 3.00%      | 18.75%        | 31.25%             | 50.00%                  | 16    |
| 9 Inspection Management        | 0.00%          | 2.00%      | 12.50%        | 31.25%             | 31.25%                  | 16    |
| 10 Tire Management             | 0.00%          | 2.00%      | 12.50%        | 31.25%             | 31.25%                  | 16    |
| 11 Work Order Management       | 2.00%          | 0.00%      | 12.50%        | 37.50%             | 50.00%                  | 16    |
| 12 GPS Tracking                | 2.00%          | 2.00%      | 12.50%        | 37.50%             | 50.00%                  | 16    |
| 13 Alerts/Notifications        | 6.25%          | 3.00%      | 18.75%        | 25.00%             | 43.75%                  | 16    |
| 14 Real Time Tracking          | 6.25%          | 2.00%      | 12.50%        | 31.25%             | 43.75%                  | 16    |
| 15 Trip Logs                   | 0.00%          | 2.00%      | 12.50%        | 31.25%             | 50.00%                  | 16    |
| 16 Maintenance Management      | 0.00%          | 2.00%      | 12.50%        | 25.00%             | 50.00%                  | 16    |
| 17 Maintenance History         | 0.00%          | 3.00%      | 18.75%        | 25.00%             | 43.75%                  | 16    |
| 18 Preventive Maintenance      | 0.00%          | 1.00%      | 6.25%         | 31.25%             | 31.25%                  | 16    |
| 19 Repair Tracking             | 0.00%          | 2.00%      | 12.50%        | 31.25%             | 31.25%                  | 16    |
| 20 Vehicle Status              | 0.00%          | 0.00%      | 6.25%         | 31.25%             | 31.25%                  | 16    |
| 21 Vehicle Cost Tracking       | 0.00%          | 3.00%      | 20.00%        | 26.67%             | 33.33%                  | 15    |
| 22 Warranty Tracking           | 0.00%          | 2.00%      | 12.50%        | 25.00%             | 50.00%                  | 16    |
| 23 Network Support             | 0.00%          | 1.00%      | 6.25%         | 25.00%             | 43.75%                  | 16    |
| 24 Auto Email                  | 12.50%         | 2.00%      | 12.50%        | 31.25%             | 31.25%                  | 16    |
| 25 Life-Cycle Cost             | 0.00%          | 2.00%      | 12.50%        | 37.50%             | 31.25%                  | 16    |
| 26 Accident Reports            | 0.00%          | 0.00%      | 18.75%        | 43.75%             | 37.50%                  | 16    |
| 27 Customizable                | 0.00%          | 2.00%      | 12.50%        | 43.75%             | 31.25%                  | 16    |
| 28 Risk Management             | 0.00%          | 0.00%      | 12.50%        | 43.75%             | 31.25%                  | 16    |
| 29 Data Import/Export          | 0.00%          | 1.00%      | 6.25%         | 37.50%             | 31.25%                  | 16    |
| 30 Available Mobile App        | 6.25%          | 1.00%      | 6.25%         | 37.50%             | 31.25%                  | 16    |