**A GPS/GIS BASED LINE OF BALANCE METHOD
FOR PLANNING AND CONTROL OF
CONSTRUCTION PROJECTS**

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FURKAN UYSAL

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ABSTRACT

A GPS/GIS BASED LINE OF BALANCE METHOD
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CONSTRUCTION PROJECTS

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In construction industry Gantt charts, network methods and Line of Balance (LOB) methods are generally used for planning and control of projects. Networking techniques such as Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) require technical knowledge and could be difficult to implement without proper scheduling background. Gantt charts and LOB techniques are usually easier to implement, however, similar to network techniques these techniques lack visualization. A graphical based scheduling and progress control method could improve existing techniques with visualization so that schedule information could be understood easily by the project participants. Geographic Information Systems (GIS) can be helpful for improving the traditional scheduling methods by utilizing spatial information.

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In this study, a prototype Global Positioning System (GPS) and GIS based LOB method is proposed. To illustrate the benefits, the proposed method will be applied to a pipeline project.

Key Words: GPS, GIS, Line of Balance Method, Planning and Control

ÖZ

İNŞAAT PROJELERİNDE PLANLAMA VE KONTROL AMAÇLI KKS/CBS TABANLI BİR DENGE DİYAGRAMI METODU

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Yüksek Lisans, İnşaat Mühendisliği Bölümü

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İnşaat sektöründe projelerin planlanması ve kontrolünde genellikle çubuk diyagramlar, serim yöntemleri ve denge diyagramları kullanılmaktadır. Kritik yörünge metodu, program tahmin ve kontrol teknikleri ve benzeri serim yöntemleri genellikle teknik bilgi gerektirdiğinden bu yöntemlerin uygun planlama alt yapısı olmadan kullanılması kullanıcılar açısından zor olabilmektedir. Çubuk diyagramlar ve denge diyagramları kullanım açısından daha kolay olmakla birlikte, serim yöntemleri gibi bu yöntemler de görsel açıdan sınırlı olanaklar sunmaktadır. İş programının görsel olarak canlandırılması program bilgilerinin idare ve kullanıcılar tarafından daha kolay anlaşılmasına olanak verebilecektir. Coğrafi Bilgi Sistemlerinin (CBS) kullanıması ile mekansal veri eksikliği kapatılabilecektir.

Bu çalışmada, prototip Küresel Konumlandırma Sistemi (KKS) ve CBS tabanlı bir denge diyagramı önerilecektir. Önerilen bu metod bir boru hattı projesinde uygulanarak faydaları gösterilecektir.

Anahtar Sözcükler: KKS, CBS, Denge Diyagramları, Planlama ve Kontrol

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LIST OF ABBREVIATIONS

CPM   Critical Path Method

LOB   Line of Balance Method

GPS   Global Positioning System

GIS   Geographic Information System

CBS   Coğrafi Bilgi Sistemleri

PERT   Program Evaluation and Review Technique

LSM   Linear Scheduling Model

RSM   Repetitive Scheduling Method

CHRISS   Computerized High Rise Integrated Scheduling System

ALISS   Advance Linear Scheduling System

CAD   Computer Aided Drawing

WAN   Wide Area Network

RTK   Real Time Kinematic

BTC   Baku-Tbilisi-Ceyhan Crude Oil Pipeline Project

UTM   Universal Transverse Mercator System

WGS84   World Geodetic System 1984

ROW   Right of Way Grading

KML   Keyhole Markup Language

XML   Extensible Markup Language

CHAPTER 1

INTRODUCTION

Construction market is becoming increasingly competitive in terms of the nature of projects which require restricted budgets and shorter project durations. Moreover, due to market conditions, it is becoming very important to complete a project within estimated budget and time. Delays may seriously impact prestige of the contractors. In addition to these, construction projects include several activities, different crews, different parties and have complex relations between each other. Thus, construction projects require careful planning and extensive control. Therefore, in construction industry better planning and control may lead to project success, while poor planning and control may result disagreements and disputes as well as serious financial losses.

Oberlender (1993) defined planning as;

- "A *benchmark for the project control system to track the quality, cost and timing of work required to successfully complete the project"*.

From this definition it can be concluded that planning compromised of controlling project quality, cost and time which all mainly depend on "*scheduling"*. Several methods have been using as scheduling techniques in construction industry. These scheduling methods bring systematic approaches to planning and control process. Gantt charts, Critical Path Method (CPM), Program Evaluation and Review Technique (PERT) and Line of Balance Method (LOB) are examples of

commonly used methods in construction industry for planning and control of projects.

Gantt charts are one of the most commonly used scheduling methods due to its simple usage and development. On a Gantt chart, horizontal axis is drawn to identify time frame, while vertical axis is drawn to identify tasks or activities to be completed. Time plan of an activity is drawn as a horizontal line from its starting date to finishing date. Moreover, progress of each activity can be drawn as simple as drawing a horizontal line from starting time to finishing time. Nevertheless, its shortcomings become obvious when projects get bigger. As the number of activities increases, it becomes tedious to update the Gantt chart. Interdependencies between activities cannot be shown either.

"Network" scheduling methods are also generally used in construction industry. One of the commonly used network scheduling techniques is CPM. It was developed in the 1950s in a joint venture between DuPont Corporation and Remington Rand Corporation for managing plant maintenance projects (http://en.wikipedia.org/wiki/ Critical_path, Last Access May 7, 2007). Since than, much software has been developed with the CPM technique which has been dominating the construction industry. CPM models activities or tasks as network where each network consisting of relatively small discrete activities. In a network, activities are shown either as a node or as an arrow. Between activities, logical relations are shown. Main principle of CPM is determining the "critical path". The significance of the critical path is that the activities on that path cannot be delayed since a delay on critical path directly effects the total completion time of the project.

The Program Evaluation and Review Technique commonly abbreviated PERT is a model for project management invented by Booz Allen Hamilton, Inc. under contract to the United States Department of Defense's US Navy Special Projects Office in 1958 as part of the Polaris mobile submarine-launched ballistic missile project (http://en.wikipedia.org/wiki/Program_EvaluationandReviewTechnique). PERT is also a network model that allows for randomness in activity completion times. Like CPM technique, it models activities as a network. Different from CPM, it includes a probabilistic approach by determining activity duration using probability distributions.

Line of Balance Method (LOB) is an alternative powerful tool for scheduling and controlling of repetitive projects. This method has been applied for pipeline construction, highway construction, tunnel and high rise construction projects. In this method, rates of production can be adjusted to have smooth and efficient flow of resources (Arditi et al. 2002a). The main assumption of LOB is activity production rate is uniform. LOB is a graphical scheduling method and more suitable to repetitive projects compared to network techniques [Albulak 1980; Arditi and Albulak 1986; Arditi et al. 2002a; Arditi et al. 2002b]. Construction schedules developed by LOB method is generally much easier to understand and follow compared to schedules developed by Gantt charts, CPM and PERT techniques for repetitive projects (Arditi et al. 2002b).

Although several scheduling and control methods have been using in construction industry, these methods usually require technical knowledge during planning and control stages. Furthermore, majority of these methods lack visualization and sometimes could be difficult to implement. Owners and project participants may

not follow the schedule and actual progress easily with existing scheduling methods. A graphical based planning and progress control method could eliminate the difficulty of visualization. Moreover, visualization could further improve the understanding of the schedule among the project participants.

In this research a GPS/GIS based Line of Balance Method will be proposed for planning and control of repetitive construction projects. The aim of this method is to visually display the schedule information so that it can be easily understood by the project participants. Moreover, with this method, information about progress of a project can easily be shared from a web page for the project participants. Detailed spatial information included in planning and progress control, would improve the coordination between project participants.

This study consists of five chapters:

- Chapter One- *Introduction*- The framework of research is proposed and research objective is introduced.

- Chapter Two-*Literature Review*- Line of Balance Method and GPS/GIS will be introduced. Literature related to Line of Balance Method and GPS/GIS applications in construction management will be reviewed.

- Chapter Three - *Research Methodology*- Method of the proposed prototype will be introduced and details of interface will be given.

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- Chapter Four- *Case Study*- The suggested methodology will be applied to a pipeline project.

- Chapter Five- *Conclusion and System Improvements*- A comprehensive review will be made both for the advantages and disadvantages of the prototype method. Potential improvements will also be included.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter includes Line of Balance Method (LOB), Global Position System (GPS) and Geographic Information Systems (GIS) studies and related applications in construction.

2.2 Line of Balance Method

LOB method was originated by the Goodyear Company in the early 1940s, further developed by the US Navy in 1952 and in the 1960s: The National Building Agency of the UK also used LOB for repetitive housing units (Yang and Ioannou 2004). Although it was developed for mainly manufacturing projects, Lumsden (1968) applied the LOB method to construction projects. The idea of repetitive scheduling was originated with the use of mass production lines where manufacturing process consists of series of workstations requiring same resources (Huang and Sun 2005). The main difference between manufacturing projects and repetitive construction projects is that *"in manufacturing it is the product being moved across stationary labor and equipment while; in construction it is the labors, equipments and materials being moved through the product (construction)"* (Yang and Ioannou 2004). LOB is a powerful tool for scheduling and controlling of projects that have repetitive activities or repetitive activity groups. Repetitive projects comprise activities that are performed continuously and repeatedly from one unit to the next, such as multi-story buildings, pipelines,

highways. In order to maintain work continuity in this resource flow, repetitive units must be scheduled in such a way as to enable timely movement of crews from one unit to the next, avoiding crew idle time (El-Rayes and Moselhi 1998).

The basis of the LOB method is to determine the required resources for every stage of construction so that the successor activities are not interfered with, while required target output is achieved (Harris and McCaffer 1989). In other words, the aim in this technique is to plan the required rate of delivery, on the required date of delivery with flow of resources from one place to other. By planning the rate of progress, it allows balancing of operations such that each activity is continuously performed. In ideal schedule all activities are performed with same rate of progress. The main difference of this method from CPM and Gantt chart is that it shows production rate of each activity together with time details in the form of a graphical format where one axis showing the progress status, other axis showing the time details. (Figure 2.1) One of the main advantages of this method compared to network scheduling techniques is that it requires smooth and efficient flow of resources and requires less preparation time to produce (Arditi and Albulak 1986).

2.2.1   Line of Balance Theory

The theory of LOB is oriented to obtain required rate of delivery in order to meet the objective of project. In theory, since the rate of delivery "m" is assumed to be constant, the relationship between the LOB quantity "q" and time "t" is assumed to be linear (Lumsden 1968). Relationship between these quantities is shown in figure 2.2 and formulized in equation (1).

$$q = m \times t + c \dots\dots\dots\dots\dots\dots\dots (1)$$
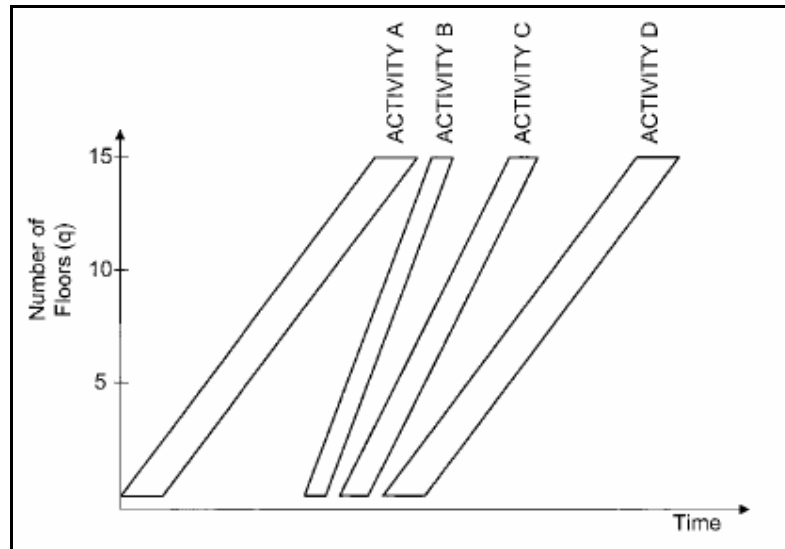
Figure 2.1: An Example of LOB Graph in Multi Story Building Construction

The development of LOB for a project is similar to other scheduling methods. These steps are;

1) Identify activities.

2) Develop activity sequence.

3) Estimate activity production rates.

4) Perform calculations.

5) Revise and adjust

The first step is "identifying activities" which is the basic step of LOB like any other scheduling techniques. Work Breakdown Structure can be used to identify project activities together with experience of planning engineer.

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The second step is "determining activity sequences". Since LOB is widely used in repetitive projects, generally a finish to start relationship exits. Main advantage of LOB over CPM in repetitive projects becomes obvious when finish to start kind of scheduling is needed. Since this kind of scheduling increases the size of network in CPM techniques, e.g. the network prepared for one unit has to be repeated "n" times, network size cannot be managed properly (Arditi et al. 2002b).
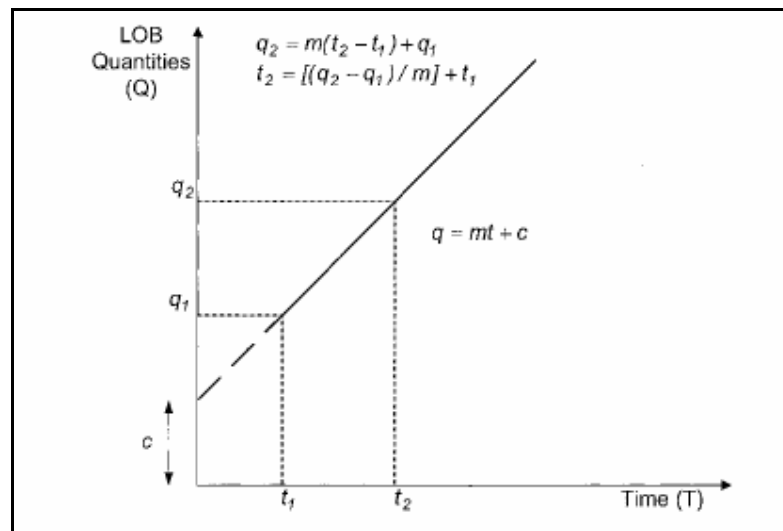
**Figure 2.2: Relationship between LOB Quantities and Time
(Arditi et al. 2002b)**

The third step is "estimating production rates" of each activity. This procedure includes estimating man-hours and determination of team sizes. After determining the production rates, the "*Natural Rhythm*" for each activity is estimated. "*Natural Rhythm*" is defined as "*the optimum rate of output that a team of optimum size is able to produce*" (Albulak 1980). Any rate of output that is different from a multiple of "*Natural Rhythm*" results in idle time for labor and equipments. After

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estimating man-hours according to "*Natural Rhythm*" buffer times for each activity is determined in order not to give confusion in terms of space and time.

The forth step is "performing LOB calculation" according to theory stated in Figure 2.2.

The last step is "revising and adjusting" the schedule. Progress measures are taken regularly from the site and these are compared with planned schedule. From these comparisons, precautions are taken to have a better balanced schedule.

2.2.2 Balancing Activity Production Rates

LOB diagrams are representation of time versus location graphs. Since the slope of this diagram measures production rate, it is also called as production curves. Actually, production curves are non-linear in nature as can be seen from Figure 2.3. Non-linearity is due to activity mobilization and demobilization in the beginning and completion. It is known that in the beginning of an activity, work output is relatively less. Thus, during early stages, slope of production curve is gentle. As production progresses, it becomes steeper which is identifying the increased output. Near completion, due to demobilization, output of work item again decreases and slope of production curve becomes gentle again. This in turn, leads a "*lazy S*" curve which is called production curve (Halpin and Riggs 1992).
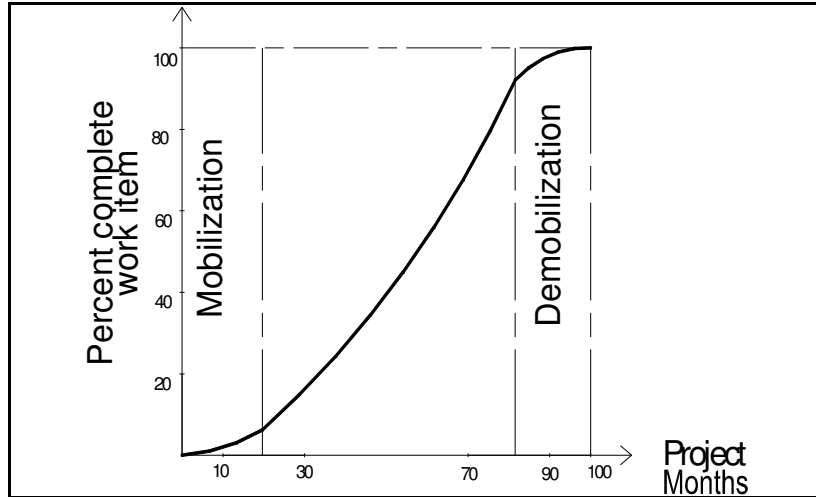
Figure 2.3: Production Curve (Halpin and Riggs 1992)
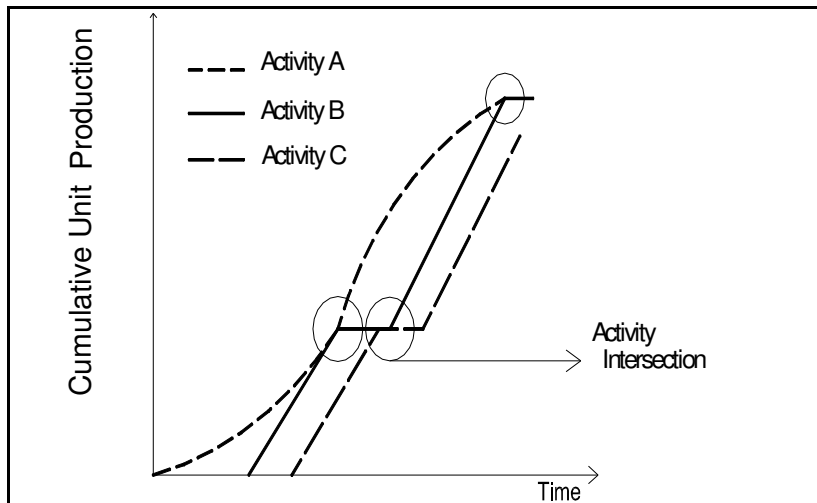
Figure 2.4: Unbalanced Process Production Rates.

(Halpin and Riggs 1992)

The need for balancing activity production rates becomes obvious when the activity number increases. If it is not done a situation like in Figure 2.4 develops. The slope of a successor activity may be so steep that it overlaps or intersects with other activities. Thus, predecessor activity may be shutdown. This is an

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undesirable situation. In order to plan the project resource workflow continuously, it is customary to balance the production rates. Therefore, LOB technique shows its necessity by adjusting the production rates so that crew continuity is established (Halpin and Riggs 1992). An example of balanced schedule can be seen from Figure 2.5.
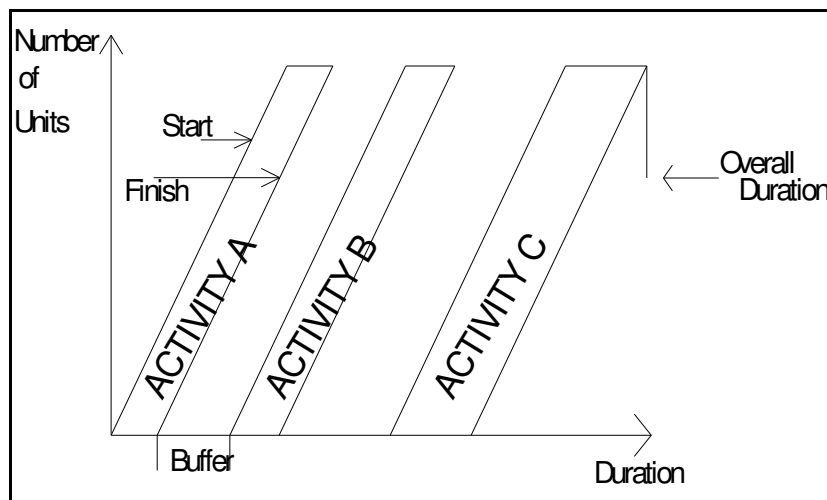
Figure 2.5: Balanced Production Rates

2.2.3 Previous Researches on LOB

It has been proposed by many researchers that LOB method is more practical to use in repetitive projects compared to "Gantt charts" and "Network" techniques [Albulak 1980; Arditi and Albulak 1986; Arditi et al. 2002a; Arditi et al. 2002b]. Nevertheless, it is not advised to be used on projects that require large number of trades due to difficulty of showing all the information on one chart (Arditi and Albulak 1986).

Albulak (1980) showed in his research that, LOB method is more useful than CPM in repetitive nature projects. He applied both LOB and CPM to a highway

construction project. Comparison between these two techniques over a highway project revealed that LOB method is useful both in scheduling and control stage due to its "*simple graphic display*" and to "*maintain work continuity*". He proposed that production rates are very useful and can be modified so as to utilize better scheduling and control. He added that, LOB method is better accepted by site personnel than CPM.

Yang and Ioannou (2004) cited that, despite the visual benefits of LOB method, critics indicate two major shortcomings.

- *"First, it has not yet been adapted to numerical computation as readily as network methods and thus requires tedious manual preparation for the production diagram" (Lutz 1990).*
- *"Second, although the manufacturing systems and repetitive construction projects are alike, repetitive projects possess their own unique characters and hence involve specific scheduling concerns that were neglected by existing LOB models*" (Russell and Wong 1993).

Harmelink (1995) proposed in his research a new method which was named as *"Linear Scheduling Model (LSM)"*. Harmelink and Rowings (1998) justified the model developed by Harmelink (1995) and illustrated the method developed for determination of controlling activity path. The method, linear scheduling model (LSM), identified the critical activities or originally named as *"the controlling activity path"*, through an upward and downward pass similar to CPM, which uses a forward and backward pass to identify the critical path. It was pointed out that widespread use of CPM depends on its capabilities such as "*resource and cost allocation*". On the other hand, LOB regarded as a "*visual technique lacking the*

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analytical qualities of CPM". Thus, determination of the critical path was a milestone that forms the basis for determination of float for non-controlling activities and provided updating linear schedule which further improves the ability of LOB to develop computerized scheduling tools. They defined four new activity types namely; Full-span linear, Partial-span linear, Block and Bar. Representation of activities defined by Harmelink (1995) can be seen from Figure 2.6.

Harmelink (1995) defined a linear activity as "*an activity that is occurring along the project from one location to another*". This may mean from floor to floor for a building, like the activity install doors or it may mean from station to station on a road job, like the activity install sub-base. A block activity is an activity "*that transpires across several locations, but lasts for an extended duration*". On the schedule, block activities are represented by a rectangle. On the other hand, the bar activity is represented as a vertical line. Different from block activities, bar activities have significantly less dimensional area than block activities but requires time in the schedule (Mattila and Park 2003). An example of a bar activity is the installation of a culvert. Examples of activities on a LSM can be seen from Figure 2.7.

Harris and Ioannou (1998) proposed a Repetitive Scheduling Method (RSM) for constructing the schedule. It was introduced that using "*control points*", the controlling sequence can be found. Control points were defined as;" *the locations on each activity line where the activity changes from controlling to non-controlling or vice versa*". The control points in the RSM schedule were used to define the controlling sequence of activities, like the critical path in a CPM schedule, which in turn determines the project duration.

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Activity Type	Abbreviation	Graphical Representation
Continuous Full-span Linear	CFL	
Intermittent Full-span Linear	IFL	
Continuous Partial-span Linear	CPL	
Intermittent Partial-span Linear	IPL	
Full-span Block	FB	
Partial-span Block	PB	
Bar	B	

Figure 2.6: Activity Types Defined by Harmelink (1995).

(Mattila and Park 2003)

Yamin and Harmelink (2001) compared LSM, which was developed by Harmelink (1995), and CPM. Comparison between two method revealed that for very specific projects (linear and continuous), LSM is superior to CPM. However, it was stated that CPM is a more complete scheduling tool than LSM, mainly because multiple resource management techniques.
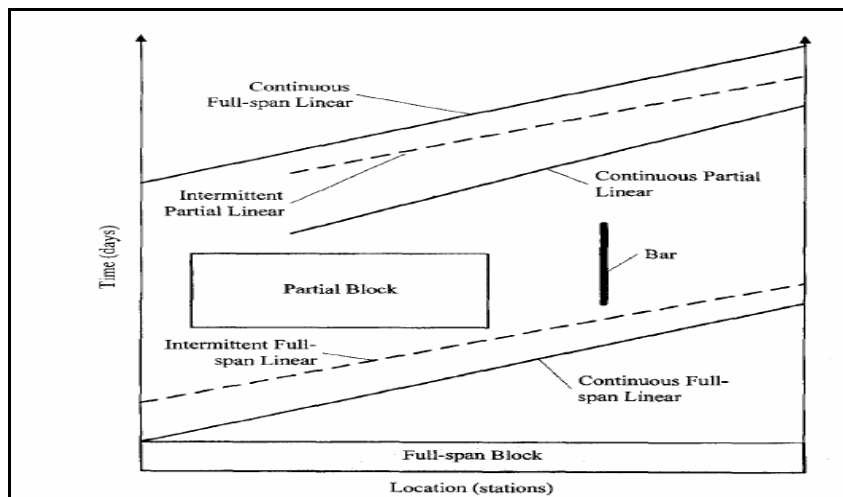
Figure 2.7: Activity types on LSM by Harmelink (1995).

(Harmelink and Rowings 1998)

Results of the study by Yamin and Harmelink (2001) can be summarized as;

- The greatest significance of the LSM over CPM is its visualization and ease of communication

- The LSM lacks some resource management capabilities. Linear Scheduling Techniques did not offer strong analytical capabilities. On the other hand, extensive research has been done in the area of resource leveling and resource allocation in network planning tools.

- CPM is appropriate when time-space relationship occur in different dimensions that cannot be represented in a two-dimensional format.

- There is no method to incorporate duration and production uncertainty into LSM schedules, as PERT does for network based scheduling methods such as CPM.

Oberlender et al. (2005) grouped projects involving repetitive activities into two; "*point-based projects*" and "*distance-based projects*". Examples of point-based projects are multi-unit housing and high-rise building construction, whereas examples of distance-based projects include pipeline and highway construction projects. It was stated that LOB method of scheduling applies to point-based projects, whereas LSM applies to distance-based projects. It was added that for point-based projects, workers perform discrete tasks to complete similar units at one or more points, whereas in distance-based projects activities are performed continuously along the length of the horizontal alignment of the projects. An example of point-based project and LOB diagram can be seen from Figure 2.8.

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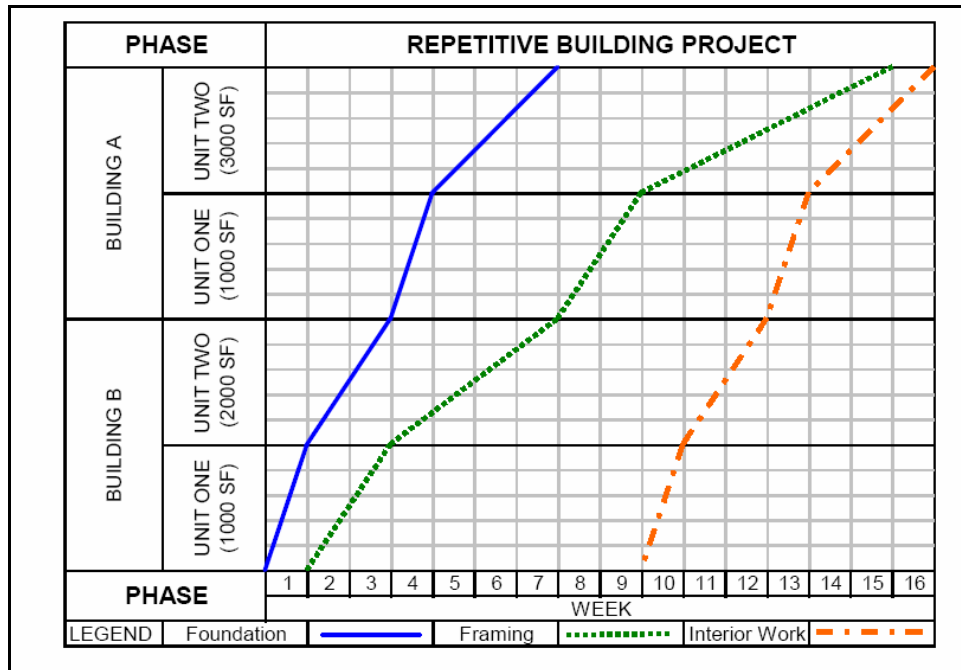
Figure 2.8: LOB for Point-based Repetitive Activities

(Oberlender et al. 2005)

Arditi et al. (2002a) set down the basic principles that can be used in the development of a computerized LOB scheduling system that overcomes the problems associated with existing systems. It was added that "*degree of detail of the LOB diagram must be carefully evaluated.*" If too many activities were plotted, the diagram would become a jungle of oblique lines that sometimes cross each other. An alternative method was also proposed, that was generating LOB diagrams of individual paths and converting LOB information into bar charts, which in turn can help alleviate visual problems of presentation. Moreover, an algorithm that performs project acceleration was proposed, which could help in optimizing total project cost. It was further advised that an alternative representation using colored lines as well as horizontal and vertical lines can help

to simplify the representation if the system is to be widely accepted by schedulers and managers.

Arditi et al. (2002b) modified the LOB approach that "*would allow user to organize the activities in a manageable way*" and that will eliminate the problems faced in computerized process with the help of an expert system. The system was named as "*Computerized High Rise Integrated Scheduling System (CHRISS)*". The aim of study was to develop a scheduling system that incorporates the basic principles LOB and Gantt chart. Moreover, expert system developed by authors acquired knowledge of high rise building construction that can be used to assist the novice planners. The two original concepts, "*flexible unit networks*" and "*multi-level LOB diagrams*", were embedded in CHRISS and allow LOB to be used in high rise building projects that display special characteristics.

Arditi et al. (2002b) stated that although network methods are very popular in larger projects, in high rise building construction it presents some complications. These are;

- "*As repetitiveness of project gets larger, size of network gets larger. For example; if one unit has to be repeated 'n' times, this results a huge network that is difficult to manage. Moreover, this may cause difficulties in communication among participants.*"
- It was added that, "*CPM algorithm is designed primarily for optimizing project duration rather than special resource constraints of repetitive project.*"

Mattilla and Park (2003) stated that network scheduling has some limitations as compared with LOB method. These limitations include;

- The arbitrary division of repetitive activities from location to location
- The inability to schedule the continuity of resources
- The large number of activities necessary to represent a repetitive or linear project in a CPM schedule
- Activity rates of progress not indicated
- A CPM schedule not accurately reflecting actual conditions
- A CPM schedule not providing any information on where on the project site the work is currently being performed.

Mattilla and Park (2003) acknowledged that all the methods in the literature so called "linear scheduling methods" produce easily interpreted graphical schedule that is "*more straightforward to understand than a network schedule*." Comparison between the two models, developed by Harmelink and Rowings (1998) and Harris and Ioannou (1998), was also conducted. It was proposed that LSM by Harmelink and Rowings (1998) provides a much more realistic controlling path for linear projects that can be obtained from CPM schedules.

Hassanein and Moselhi (2005) presented a method and algorithm to schedule linear repetitive construction projects such that they meet a "*pre-specified targeted completion date, or the closest possible date*". A two-stage iterative process was employed to reduce project duration. In first stage, the lead and lag times between successive activities were compared in the in order to identify the

activity that is most suited to accelerate project completion. In the second stage, the expediting strategy that would reduce project duration was utilized.

Yang and Ioannou (2004) pointed out that all LOB diagrams have visual benefits of showing production rates and locations of crews on production charts. It was added that there is no computational algorithm to calculate and generate the production diagram. Therefore, a Repetitive Scheduling Model (RSM) computational algorithm which was designed and it is programmed into a computer software, RP2, in order "*to replace the tedious manual preparation of conventional LOB models" and "hence allows project managers to rapidly test various strategies or perform what-if analyses by varying production rates, crew sizes, work sequencing, etc.*" Algorithm was to compute the start time of every activity together with minimum project duration under precedence constraints. Moreover, an interview was conducted between project managers and practical concerns of repetitive scheduling projects were identified.

Yang and Ioannou (2004) proposed that future efforts should concentrate on two perspectives.

- "*First, a cost-loading feature should be incorporated into RP2*".
- "*Second, the improved readability of RSM diagrams should be enhanced*".

Tokdemir et al. (2006) developed a computerized scheduling system called "*Advance Linear Scheduling System (ALISS)*". Owing to the limitations of the program that is applicable to only high rise buildings, CHRISS was criticized by Tokdemir et al. (2006). Other shortcoming of CHRISS was it could not operate in

Windows XP environment. ALISS was developed with visual basic program and was compatible with Windows XP environment.

2.3 Global Positioning System in Construction Management Practice

Global Positioning System (GPS) is "*a network of satellites that continuously transmits coded information, which makes it possible to precisely identify locations on earth by measuring distance from satellites*" (Garmin 2000). Although system was established for military use, civil usage is also possible. Working principle of GPS is based on radio navigation, which starts with the satellites transmitting low frequency radio signals. Radio signals pass thought the atmosphere and reach to ground. Then, a GPS receiver can detect the signals and can calculate the coordinates of a location.

Although GPS is commonly being used in several engineering applications, usage in construction management is limited. In construction management practice, previous research mainly focused on automation of earthwork calculations [Tserng et al. 2000; Tserng and Russell 2002; Navon et al. 2004]. Other GPS related studies were about material management (Li et al. 2005), real time equipment and labor positioning [Sacks et al. 2003; Lu et al. 2006], autonomous construction plant control (Roberts et al. 1999) and determination of impact of construction on highway traffic flow (Garcia et al. 2006).

Tserng et al. (2000) developed an interactive path planning model for multi-equipment landfill operations. Model proposed a 3-D graphical interface with

real-time tracking and motion planning features for project managers during site work. Aim of the study was to present an interactive motion planning and control system to assist operators or project managers in order to achieve the most efficient movements during the autonomous landfill compaction. Within this research, an efficient geometric model establishing in site traffic networks, and finding collision free and shortest path for equipment was asserted. Real time distance measurements were taken with GPS receivers. (Figure 2.9)

A 3-D graphical database system for solid waste management of a landfill site was developed by Tserng and Russell (2002). (Figure 2.10) Landfill configuration obtained roughly by a CAD model was measured again by a GPS receiver which is mounted on a truck. Receivers were allowed to measure moving through the fill site. During waste fill compaction, surface conditions are updated and monitored on real time basis. Therefore, space consumption and waste information were obtained and monitored easily by GPS measurements.
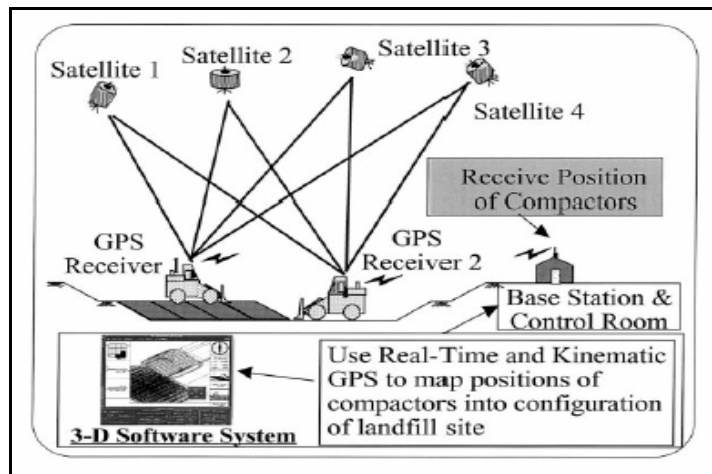
Figure 2.9: 3-D Model for Multi-Equipment Landfill Operations Developed by Tserng et al. (2000)

A prototype automated earthmoving control system was developed by Navon et al. (2004). It was asserted that traditional control systems are based on manual data collection, which turns out to be inaccurate and slow. Thus, manual data was stated as an "obstacle" for automated control systems. Moreover, a survey was conducted for investigation of an automated earthmoving control system. As a result of that survey, it was revealed that there was an urgent need for such a system in order to control the earthwork efficiently. The system presented in this research was based on the concept of measuring the equipment's location at regular time intervals with a GPS receiver, and converting it into the controlled parameters such as productivity measurements and materials consumption.
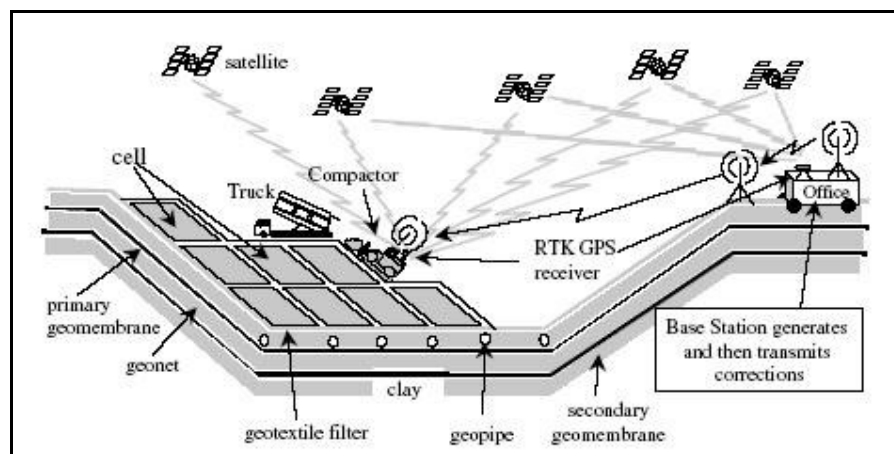
Figure 2.10: 3-D Graphical Database System for Solid Waste Management by Tserng and Russell (2002)

Li et al. (2005) applied both GPS and GIS technology for reduction of construction waste. It was pointed out that total amount of construction waste still out of control due to massive urban development projects and lack of effective tools. Research was examined to investigate barcode systems with GPS, GIS and Wide Area Network (WAN) technology to facilitate material and equipment

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management to control and reduce construction wastes. A case study was conducted and proposed system was tested.

Sacks et al. (2003) asserted an automated labor monitoring method. Workers were monitored automatically by GPS technology which is placed on workers' helmets. Workers position together with physical geometry of a building was mapped on software. (Figure 2.11) Research was proposed that full integration of automated data monitoring systems with building project models was an effective method to measure project performance indicators such as labor productivity, material consumption or waste, and demonstrates how integration could be accomplished.
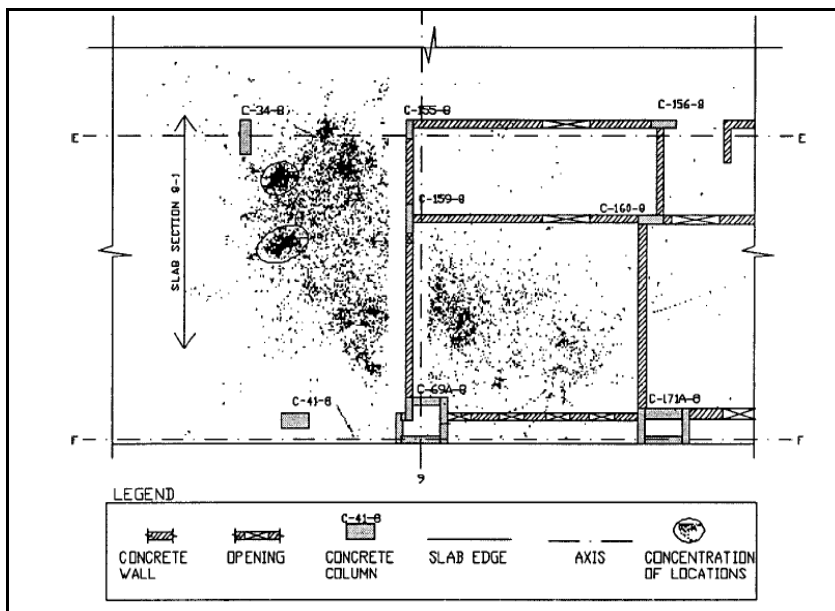
Figure 2.11: Mapping Raw GPS Data with Labor Positions
(Sacks et al. 2003)

Lu et al. (2006) investigated the tracking of construction equipment movements by using GPS technology in high dense urban area. It was concluded that, GPS

receivers severely effected in such areas. Potential problem was pointed out as unavailability of GPS fixing and decreased accuracy.

Roberts et al. (1999) investigated the use of GPS technology for construction plant control and guidance. Laser controlled construction plant was compared with GPS controlled one. It was demonstrated that Real Time Kinematic (RTK) GPS for control systems can provide coordinate precisions of a few millimeters, when a reference receiver is located close by less than 1 km at a point of well-defined coordinates. A GPS-based system offers the potential to provide continuous 3-D control, over large areas and at the same level of centimeter accuracy as compared to laser systems, with the only limitation being that of line of sight to the satellites.

Garcia et al. (2006) examined the effect of a highway construction on traffic flow. A GPS receiver is mounted on a car and measurements are taken in terms of geodetic data and time. Locations such as construction limits, activity area were recorded by the GPS device, providing a snapshot of the traveling conditions on a particular date and time. It was added that such a capability to maintain log information for queues that can occur when different construction activities are in progress would be very useful for future works in order to guess the effect of construction activities on traffic flow.

2.4 Geographic Information Systems in Construction Management

"*A geographic information system (GIS) is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth. It allows users to create interactive queries (user created*

searches), analyze the spatial information, edit data, maps, and present the results of all these operations." (http://en.wikipedia.org/wiki/ Geographic _information_system, Last access May 15, 2007) Specially applied to modeling and used as database in civil engineering, GIS has been recognized widely as a beneficial technology.

GIS has been using commonly for modeling purposes. Modeling in civil engineering aims to understand the nature of engineering problems. With spatially referenced data, GIS assists engineers to visualize the problems associated with the mechanism of models. This visualization improves the understanding of physical phenomenon. These 3-D spatially referenced tools allow users to generate and visualize physical phenomenon through high resolution scenes.

GIS stores information about the world as a collection of layers that can be linked together by geography. (Figure 2.12) GIS can handle both spatial and attribute data where spatial data relate the geometric features, while attribute data relate characteristics of different features (Bansal and Pal 2007). GIS work with two fundamentally different types of geographic models the "vector" model and the "raster" model in order to describe spatial relations. In the vector model, information about points, lines, and polygons is stored as a collection of x, y coordinates. The location of a point feature, such as a house, can be described by a single x, y coordinate. A raster image comprises a collection of grid cells rather like a scanned map or picture (http://www.dedham-ma.gov/index.cfm?pid=12728, Last Access June 01, 2007).

Although there has been major advances in GIS technology and its widespread usage in engineering, there are limited GIS related research in construction management practice. Cheng and O'Connor (1996) developed an automatic site layout system which was used to locate temporary facilities in construction. Objective of the study was to develop a system that identifies the areas suitable for temporary facilities in order to minimize construction conflicts and improve the project efficiency. Temporary facilities were defined as *"facilities located on site to support construction operations."* Efficient temporary facilities were used as job offices, warehouses, workshops where workforce, traveling, material and equipment handling, travel distance, traffic interference are optimized. .
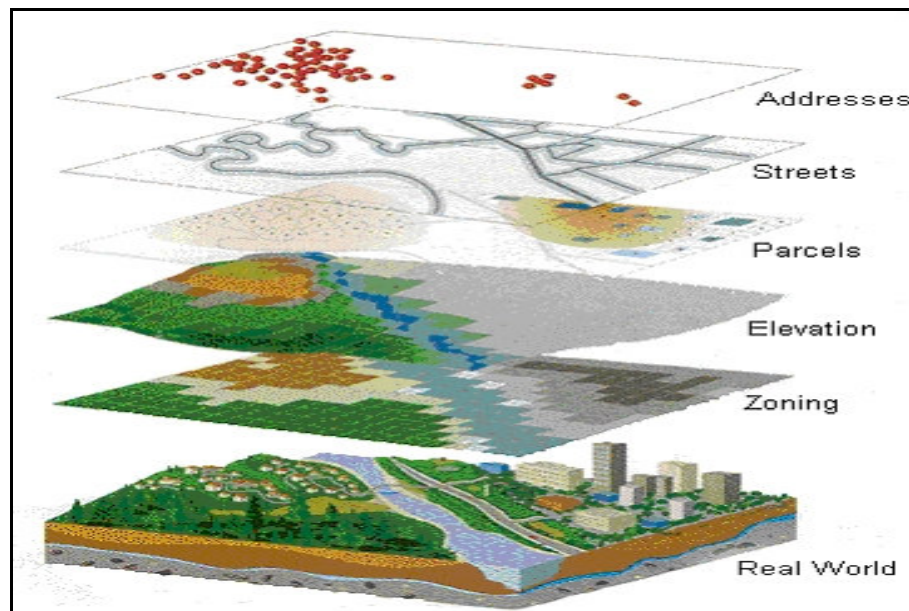
Figure 2.12: GIS Layers

Cheng and Yang (2001) proposed a system that assists managers to locate suitable material storage in site which combined the capabilities of GIS for cost estimation. The developed tool *"Materialplan"* can be used as an assistant tool in

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quantity takeoffs and material layout in site which have potential to replace manual methods.

Cheng and Chen (2002) introduced an automated schedule monitoring system integrated with barcodes and GIS, specifically designed for assisting the managers to control the erection process for pre-cast building construction. The operational structure for job site scheduling control had four parts which can also be seen from Figure 2.13, including:

- wireless bar code transmit system
- on-site control center
- automated data collection using bar code collector
- V8 video monitoring.

It was concluded by Cheng and Chen (2002) that the integration of schedule and design information makes it easy for the project manager to monitor and control the erection progress.

Poku and Arditi (2006) asserted a study which integrated GIS and CPM schedule. Aim of GIS application was for progress control in a building construction. Study was utilized to display the progress and sequence of construction work in CAD format with different colors and labels in 3-D environment with the help of GIS software, while synchronizing with a formal CPM work schedule. It was further pointed out that this form of presentation helps to visualize the progress for all parties involved in construction in a natural way by providing spatial knowledge with CPM schedule. The main advantage of this system defined as; it increased

the effective communication among project participants by showing 3-D information with schedule information on the same screen.
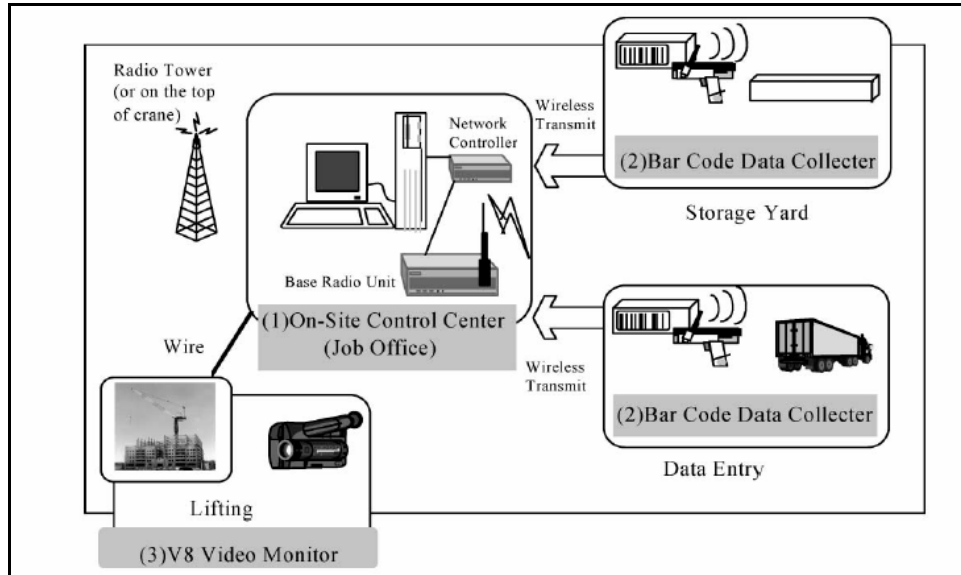
Figure 2.13: Operational Structure for Job Site Scheduling and Control (Cheng and Chen 2002)

Bansal and Pal (2007) investigated the potential use of GIS in building construction for cost estimating. A methodology was asserted which was combining cost estimation with 3-D visualization. A case study was provided for 3-D visualization and cost estimation using a residential building. Study was demonstrated that GIS can be used for storing and utilizing information related to resources which in turn help in planning process, quantity take-offs, and cost estimation.

The literature review yielded that, LOB method has been using commonly in projects that are repetitive in nature. Research that have been conducted so far, mainly focused on development of computerized scheduling algorithms for LOB

method. One challenging study by Harmelink (1995) was development of critical path. On the other hand, there has not been any attempt to visualize LOB method in 3-D environment with time frame integration.

The use of GPS and GIS in construction management is limited. GPS usage was mainly focused on automated earthwork calculations and real time equipment tracking, while GIS was used mainly for site layout purposes. There has been one study in which GIS and CPM was integrated (Poku and Arditi 2006). On the other hand, GIS is an improving tool for many research areas in civil engineering. It is concluded that, GIS based planning and control of projects is a promising area and has to be studied by researchers in detail which would improve the spatial knowledge need both in planning and control stage.

CHAPTER 3

RESEARCH METHODOLOGY

3.1   Introduction

The intend of the method presented in this research is to demonstrate that with GPS and GIS tools, it is possible to display schedule information visually for planning and control purposes. In this study, GPS is used to gather geodetic information about activity progresses along line of sight of a repetitive project. Together with the geodetic and schedule information, progresses will be modeled on GIS software with time frame integration. By this kind of visualization, schedule information could be easily understood by the project participants. This could enable not only improved acceptance of the schedule but also improved control.

3.2   GPS/GIS Based LOB Method

The first step of proposed is gathering the GPS and schedule data for the activities. The need behind this kind of GPS information is not for measurement of any kind of physical property; rather to display the geodetic coordinates visually. Thus, precision of GPS data is not a concern of this study. For every predetermined station kilometer, e.g. every kilometer, progress of each activity, in terms of both GPS and schedule information, is recorded at the construction site. These data are compiled in order to see progresses visually with GIS software. This kind of huge data is systematically grouped like in Table 3.1.

To see the progresses visually, every activity is modeled on GIS software, as a colored line which extends from one point to any other, at a particular time frame. For every activity extending from one point to other, a colored line included layer is created by the software. With the help of GIS software, station kilometer of points, can also be included to the model as another layer. An example can be seen from Figure 3.1. For activity 1 from station KM1 to KM2 a colored green line is drawn at time frame "Date 1". At the same time, progress of other activities can be seen with other colored lines. In the same manner, another layer is created to see the progress at Date 2. This procedure goes on for every activity until whole progress is modeled.

St.Km.	East	North	Elevation	Activty1	Activty2	Activity3
KM 1	X_1	Y_1	Z_1	Date 1	Date 4	Date 7
KM 2	X_2	Y_2	Z_2	Date 2	Date 5	Date 8
KM3	X_3	Y_3	Z_3	Date 3	Date 6	Date 9

Table 3.1: Data Table Format

Known LOB method is a 2D graphical model, on which, schedule is displayed as a graph, with time on one axis and location on other axis. In the same manner, trough this method, location information is visually represented in 3-D environment and time frame is included to the model. Any particular time,

progress can be visually seen from GIS software by representation of activities with colored lines which are drawn at different elevations. (Figure 3.1)
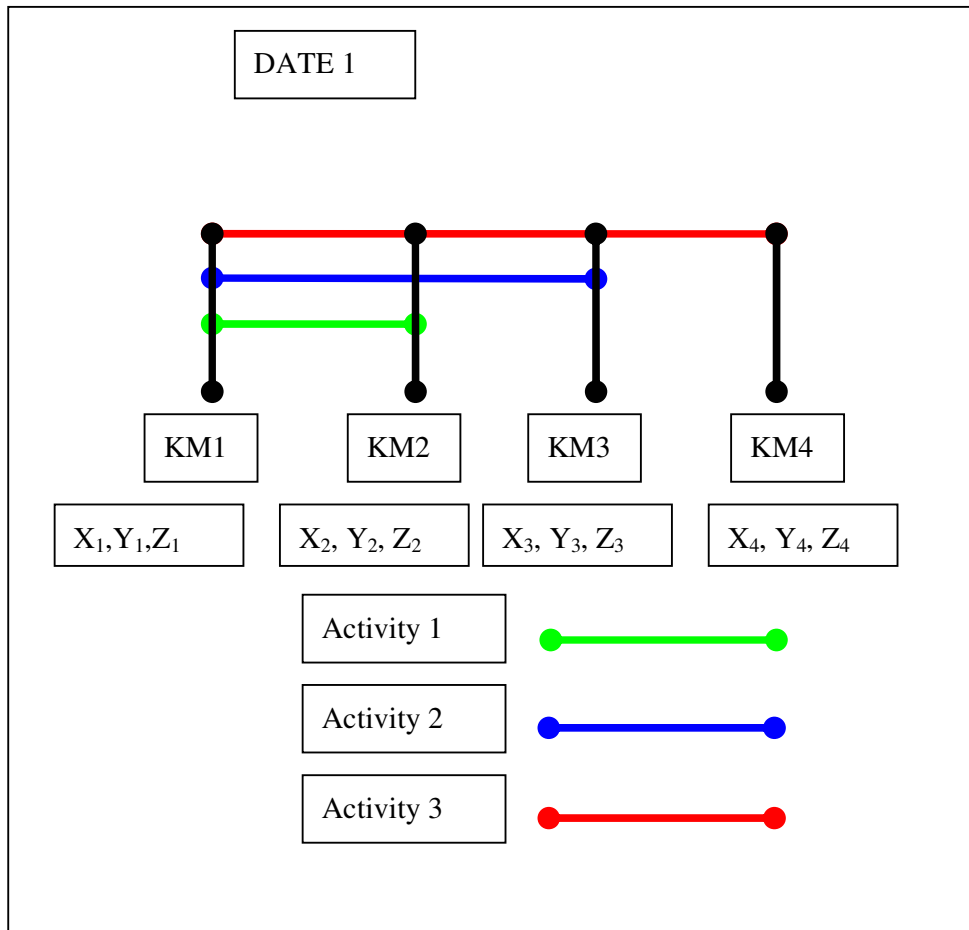
Figure 3.1: Activity Progress Representation with GPS Data and Time

3.2.1 GIS Software Used in This Study

GIS tools have been widely used in modeling purposes. There are lots of commercially available software programs. On the other hand, these professional programs are too expensive to buy for this kind of prototype research. For this

reason, a freeware and widely known software "Google Earth" was used as the modeling tool.

"Google Earth" software is a freeware version of "Google Earth Professional". It can be downloaded from its' web site with free of charge. Due to its widespread usage and being freeware, lots of applications and models has been developed using this software. It works under a language which is named as "Keyhole Markup Language (KML)". KML uses a "tag" based structure with nested elements and is based on the XML standard. This language allows users to model any kind of physical property including spatial and non-spatial data.

The problem with this software is development of KML files for modeling purposes since there is not an editor program that help to generate this kind of files written with KML language. Manual writing KML files is a tidy job and is not feasible. Therefore, an interface which automatically generates KML files was written in the scope of this study with C++ language in order to automate the modeling method. Procedure of modeling a point, a line, and line with time in KML can be seen in the following section. The interface written for this study and its working principle also included in this chapter. Codes of the interface developed in the scope of this method can be found Appendix-A.

3.2.1.1 Modeling a Point in Google Earth

Point is named as "Placemark" in this software. In order to locate a point, a KML file which contains tags for "Placemark" has to be generated for each point. The order of tags can be seen from Figure 3.2.

```
<Placemark>  <name>Name of Placemark</name>
<description>Some Descriptive text.</description><Point>
<coordinates>"Coordinates of point is
written"</coordinates></Point></Placemark>
```

Figure 3.2: Placemark Generation

3.2.1.2 Modeling a Line in Google Earth

In order to generate a line from one point to other, the code on figure 3.3 has to be written to a KML file for each of the line to be drawn.

```
<LineString>
  <extrude>1</extrude>
  <tessellate>1</tessellate>
<altitudeMode>relativeToGround</altitudeMode>
  <coordinates>"Coordinates of line is written"
  </coordinates>   </LineString>
```

Figure 3.3: Line Generation

3.2.1.3 Modeling a Line with Time Synchronization

In order to model a line with time frame, codes shown on figure 3.4 has to be written for each and every colored line.

```
<Placemark> <Style> <LineStyle>
<color>"color of line"</color>          <width>"width
of line"</width> </LineStyle>          </Style>
<tessellate>1</tessellate> <LineString>
<extrude>1</extrude>
<altitudeMode>absolute</altitudeMode>
<coordinates> "Coordinates of point is
written"</coordinates> </LineString>      <TimeSpan>
<begin>"beginning date"</begin>          <end>"end
date"</end> </TimeSpan> </Placemark>
```

Figure 3.4: Line Generation with Time Synchronization

3.2.1.4 Interface Details

For every line and point to be drawn in Google Earth, a KML code has to be written in this software. The codes shown on the Figure 3.4 model only one line and its integration with time. In the same manner, almost 500 pages of code have to be written in order to model the whole progress. Yet, this procedure cannot be completed manually. Therefore, a program which works for modeling the progress was written in the scope of this research with C++ language. Interface of the program can be seen from Figure 3.5.

Figure 3.5: Interface Written for KML File Generation.

The aim of this interface is to automate the model asserted in this study. Working principle of the interface is as follows:

1) From "Browse" button excel file which contains GPS and Time information is selected. Data should be in the format of Table 3.1

2) Activities defined in excel file automatically selected with "Activity" combo box.

3) For every activity selected, a color is defined from "Color" combo box via a color selection tool. (Figure 3.6)
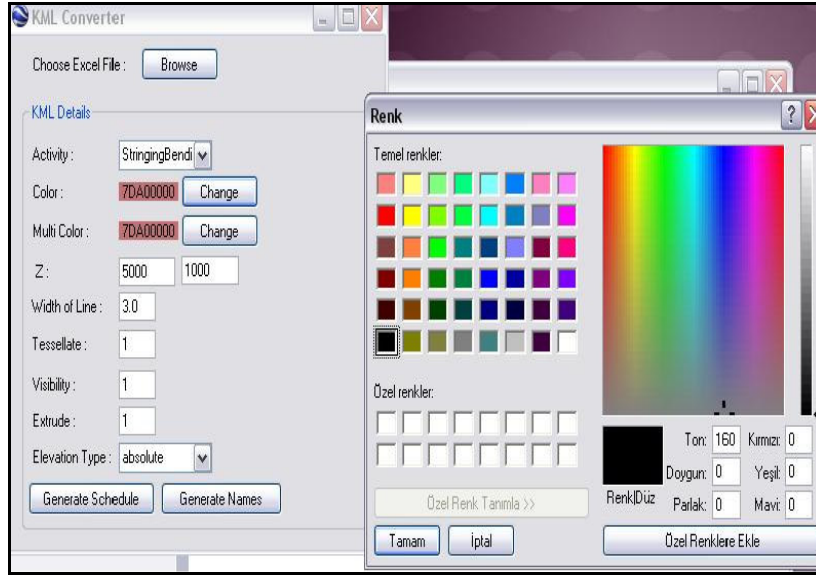
Figure 3.6: Color Selection for Activity Representation

4) If whole progress is to be modeled, elevation decrease for each activity representation is entered to "Z" text box.

5) Width of lines is entered to "Width of line" text box.

6) If the line is to be drawn parallel to ground "1" is entered to "tessellate" text box. Otherwise lines are drawn parallel to physical geometry of terrain.

7) If 1 is entered to "visibility" text box, lines are become visible.

8) On "Extrude" button it can be entered either 1 or 0 depending on the representation type of lines. If 1 is entered, lines are drawn with different altitudes and each of them can be seen from an extruded geometry.

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9) Altitude mode can be selected either "relative to ground" or "absolute".

10) Finally KML file containing the model is generated with "Generate Schedule" button. If the station kilometers are to be included to the model "Generate Name" button is used.

Details and theory of the GPS/GIS based LOB method was introduced in this chapter. In this method, for every activity, schedule information is modeled as a colored line extending from one predetermined point to other with different altitudes. Since GIS tools are expensive, a freeware version of Google Earth was used in this study. An interface was written in order to obtain" KML" files for modeling in Google Earth. With this representation, schedule information can be shared between project participants more easily. Moreover, this visual representation of schedule information makes this method easier to understand than LOB method.

CHAPTER 4

CASE STUDY

4.1   Introduction

Since LOB method is generally used for repetitive projects, proposed GPS/GIS based LOB method will be applied to a pipeline construction project. In the first part of this chapter, data and activities used in this case study will be introduced. Afterwards, case study including as planned schedule and as built schedule will be demonstrated.

4.2   GPS Data Gathering

Data used in this study was gathered from Baku-Tbilisi-Ceyhan Crude Oil Pipeline (BTC) project. The schedule and GPS data was obtained from one oof the main contractors involved in BTC project. Since proposed method uses GPS data as an input, from drawings GPS coordinates along pipeline was identified. Drawings were firstly based on Universal Transverse Mercator (UTM) coordinate system. Afterwards, this coordinate system was converted to World Geodetic System (WGS84) by a excel macro program, in order to obtain GPS data. By this conversation, about eighty points along line of sight of pipeline project was determined.

4.2.1 Baku-Tbilisi-Ceyhan Crude Oil Pipeline Project (BTC)

Case study was done with real GPS data, a real as-planned schedule and as built schedules on BTC pipeline project including only the section between Pump Station 1 to Pump Station 2 of whole line (Figure 4.1). BTC is developed for the purpose of transporting crude oil which is produced in Azerbaijan to Ceyhan via Georgia. The BTC pipeline transports crude petroleum 1,776 km from the Azeri-Chirag-Guneshli oil field in the Caspian Sea to the Mediterranean Sea. The total length of the pipeline in Azerbaijan is 440 km long, in Georgia it is 260 km long and in Turkey is 1076 km long. There are 8 pump stations through the pipeline route. It passes through Baku, the capital of Azerbaijan; Tbilisi, the capital of Georgia; and Ceyhan, a port on the south-eastern Mediterranean coast of Turkey. The first oil that was pumped from the Baku end of the pipeline on May 10, 2005 reached Ceyhan on May 28, 2006 (http://en.wikipedia.org/wiki /Baku-Tbilisi-Ceyhan_pipeline, Last Access 07 June, 2007).

BTC pipeline was one of the largest engineering projects in the region. It was constructed from 150,000 individual joints of line pipe, each measuring 12 m in length. This corresponds to a total weight of approximately 594,000 tons. Filling the pipeline with crude oil between Azerbaijan and Turkey's Mediterranean coast began on 25 May 2005. BP holds a 30% stake in the consortium running the pipeline. Other consortium members include Azerbaijan's state oil company SOCAR (25%), Amerada Hess (2.36%), ConocoPhillips (2.5%), Eni (5%), Inpex (2.5%), Itochu (3.4%), Statoil (8.71%), Total-FINA-ELF (5%), TPAO (6.53%) and Unocal (8.9%). The pipeline was constructed by, the consortium company

Baku-Tbilisi-Ceyhan Pipeline Company (BTC Co) (http://www.hydrocarbons-technology. com/projects/bp/, Last Access June 07, 2007).
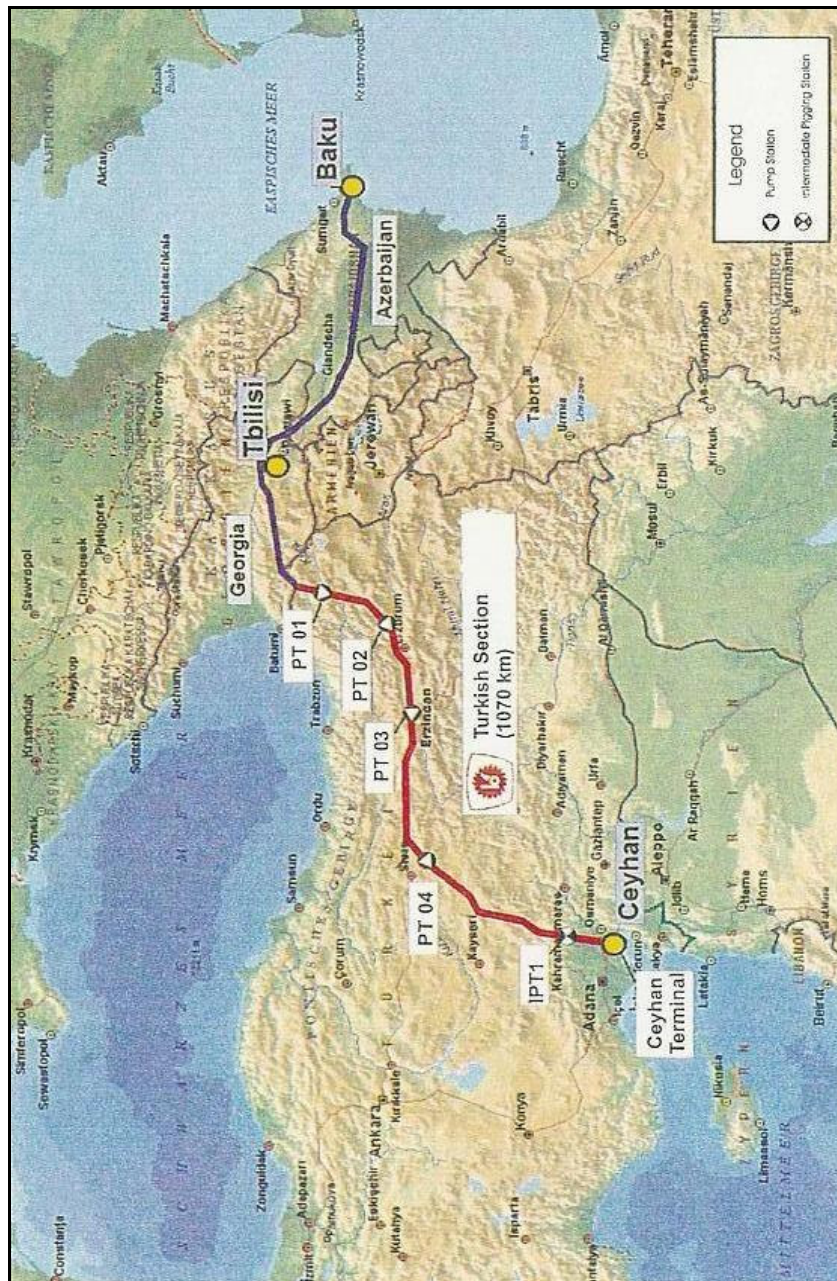
Figure 4.1: BTC Crude Oil Pipeline Project

4.2.2 Selected Activities in Case Study

In this case study, ten activities are identified and used with the proposed method. These activities are; Pre-construction Survey, Right of Way Grading, Stringing and bending, Welding, Coating, Ripping and Trench Excavation, Padding, Hydro Test, Clean Up, Pig Run. In order to better understand the pipeline construction, these activities are explained as;

- **Pre-construction Survey:** Before construction begins, environmental features along proposed pipeline segments are determined. Utility lines, agricultural drainages, are located and marked; next, the pipeline's centerline and the exterior right of way boundaries are identified.

- **Right of Way Grading:** To begin construction the selected route (Right of Way, ROW) of the pipeline must be cleared. All trees, grasses and any other obstacles on the ROW are removed. Construction work and equipments requires work space that is to be used through construction work. To make the right of way into a suitable work area, a clearing and grading crew prepares the corridor so the construction equipment can operate safely. This crew removes trees, boulders, brush, and other obstacles that may prohibit construction.

- **Stringing and Bending:** After clearing the construction rights-of-way sufficiently to allow construction equipment to work and gain access, sections of pipe are laid out along the ROW of the pipeline. (Figure 4.2) This process is called 'stringing' the pipe. Since different pipe types may

be used along the construction of a pipeline, it is very important to place right pipe types to right places in "stringing". "Bending" is shaping the pipes suitable to route itself. Bending angles, grades are applied to pipes in order to fit the geometry of the route.

Figure 4.2: Stringing and Bending
(http://primis.phmsa.dot.gov/comm/PipelineBasics.htm, Last Access June 07, 2007)

- **Welding:** Welding is the process that joins the various sections of pipe together into one continuous length. In natural gas pipelines it is a very important activity since any gas runaway may lead explosion. Therefore, welding activity not only includes welding itself, but also includes testing. Generally contractors use automatic welding equipments so as to maintain specific quality throughout the work.

- **Coating:** Pipes are externally coated to inhibit corrosion by preventing moisture from direct contact with the steel. Generally, pipes are coated at production site, but to allow welding some parts remain uncoated. Therefore, this activity is done to ensure that whole pipe is coated.

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- **Ripping and Trench Excavation:** In this activity, in order to bury pipes, mechanical equipment such as wheel trenchers or backhoes is used to dig a pipe trench. Sometimes, rock drilling and blasting is required to break rock. The material that is excavated during trenching operations is temporarily stockpiled on the non-working side of the trench. This material will be used again in the backfill operation. Afterwards, pipes are slowly lowered down into trenches with special machines. This activity is called "Ripping". (Figure 4.3)

- **Padding:** It is important that large rocks in the trench do not come into contact directly with the pipe. In case of any uncontrolled contact pipe may be damaged and it may further cause unnecessary corrosion of the pipe. For this reason, it is common to fill the trench excavation surrounding the pipe with fine material which has been separated from the soil. This process is known as padding.

- **Hydro Test:** Before being placed into service, all newly constructed dangerous liquid and natural gas transmission pipelines are hydrostatically tested. The purpose of a hydrostatic pressure test is to find out any defect that might threaten the pipeline's ability to sustain its maximum operating pressure. Hydrostatic pressure testing is done with of filling the pipeline with water and raising the internal pressure to a specified level above the intended operating pressure. Critical defects that cannot withstand the pressure will surely fail during testing. Upon detection of such failures, the defects are repaired or the affected section of the pipeline is replaced and the test resumed until the pipeline passes the test.

- **Clean Up:** The construction right-of-way is restored and it is converted as closely as possible to its original condition. Depending on the location and circumstances, this could involve smoothing the construction area, replacing topsoil, repairing irrigation systems, applying grass seed, removing large rocks that may have been brought to the surface or other actions that may be necessary.

Figure 4.3: Ripping and Trench Excavation
(http://www.hydrocarbons-technology.com/projects/bp,
Last Access June 07, 2007)

- **Pig Run:** Pipeline pigs are devices that are inserted into a pipeline which travel throughout the length of a pipeline driven by a product flow. They were developed to remove deposits which could obstruct or retard flow through a pipeline. Therefore, in this activity pigs are run through pipeline in order to be sure against any problem with the flow.

4.3   GPS/GIS Based LOB Method as a Planning Tool

In this section, it is intended to demonstrate how proposed GPS/GIS based LOB method can be used for planning purpose. For this reason, real as-planned schedule of BTC pipeline project is used with comparison to LOB method.

4.3.1. Planning with Traditional LOB Method

It can be seen from Figure 4.4; as-planned schedule of real case was drawn using real GPS and time data. It was assumed in real schedule that, through each activity, 1000m/day of balanced progress could be achieved.

Some milestones were identified from LOB graphic (Figure 4.4) in order to compare it with GPS/GIS based LOB method. These are;

- Pre-construction Survey was started on May 14, 2003,
- ROW Grading was started on 23 June, 2003,
- Stringing Bending was started on 02August, 2003,
- On August 21, 2003, It was determined that Pre-construction survey was reached to station km. 96, ROW grading was reached to station km. 60, Welding was reached to station km.18, Coating was reached to station km. 3,
- Between the dates 02 December, 2003 to 14 April, 2004 it was planned not to start any activity in site due to winter conditions.

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4.3.2 Planning with GPS/GIS Based LOB Method

In order to compare LOB method with the GPS/GIS based LOB method, same color legend is used in this section of the research. Same data was used as in Figure 4.4. With the help of interface, KML based modeling files were generated in order to model the planning process of the project. After generating the KML file, it was opened with Google Earth program, and results are tabulated through Figure 4.5 to Figure 4.10 in the following pages. Comparison can easily be made with Figure 4.4 and other Figures from 4.5 to 4.10.
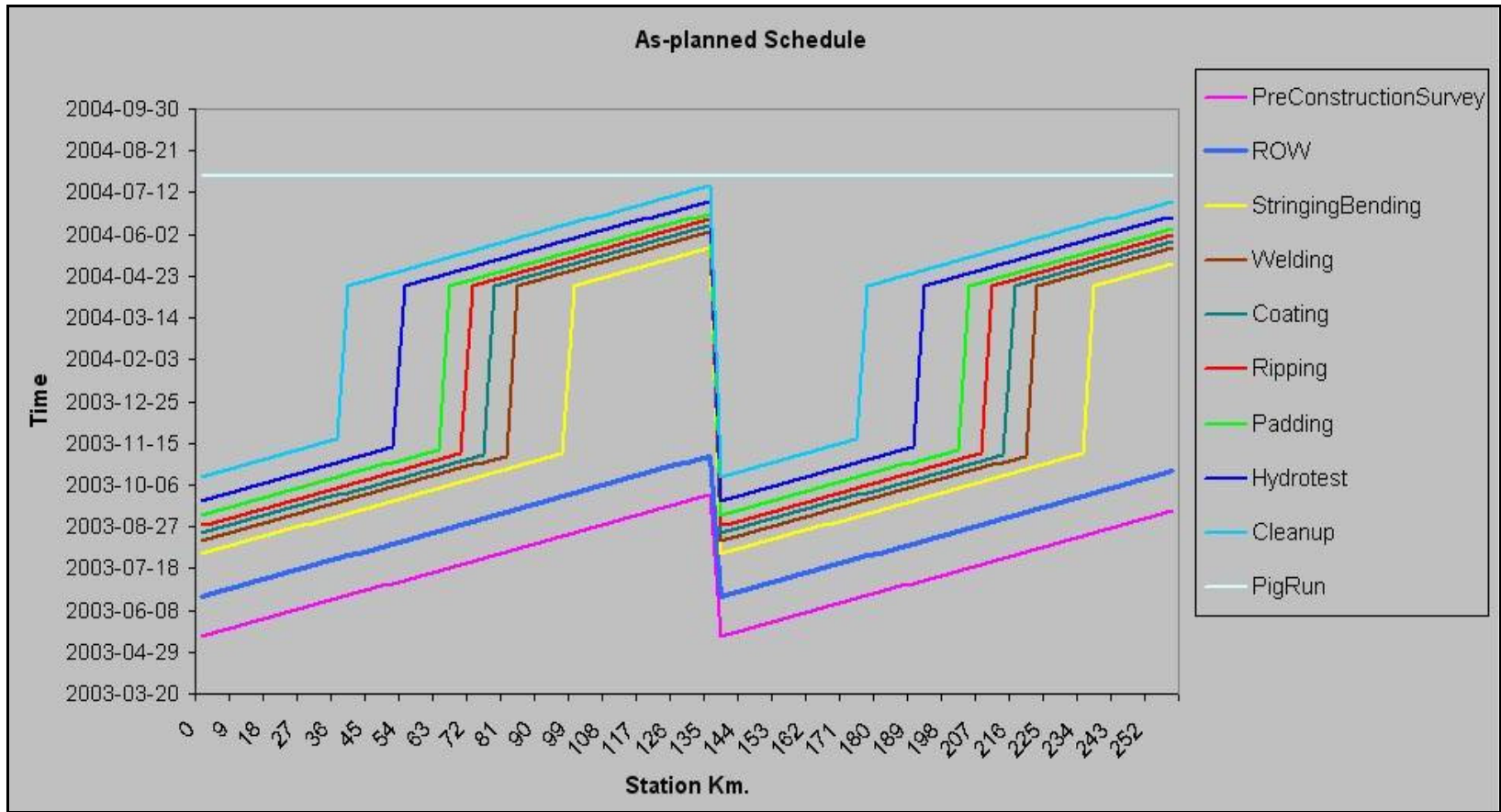
Figure 4.4: As-planned Schedule
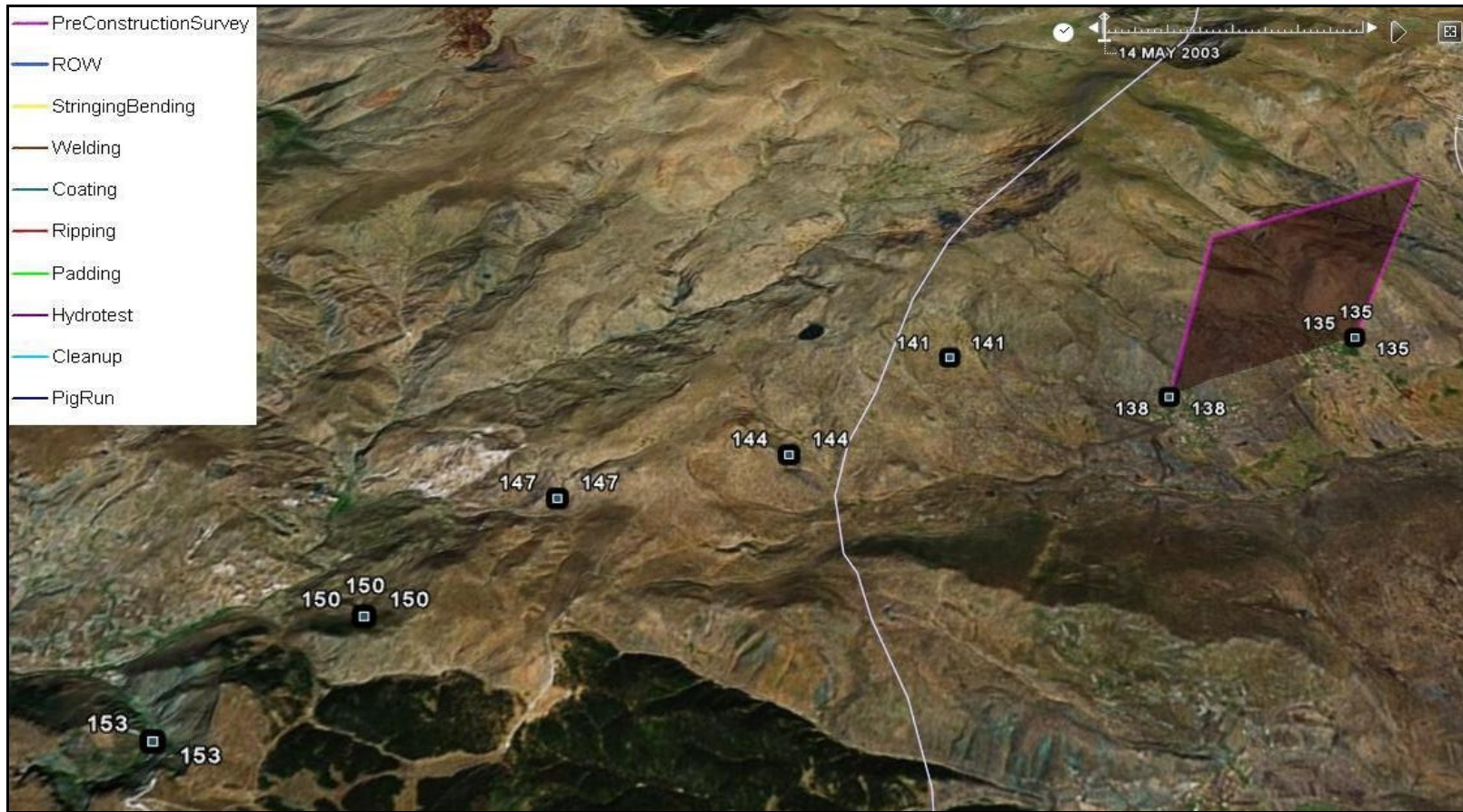
Figure 4.5: Preconstruction Survey was started on May 14, 2003
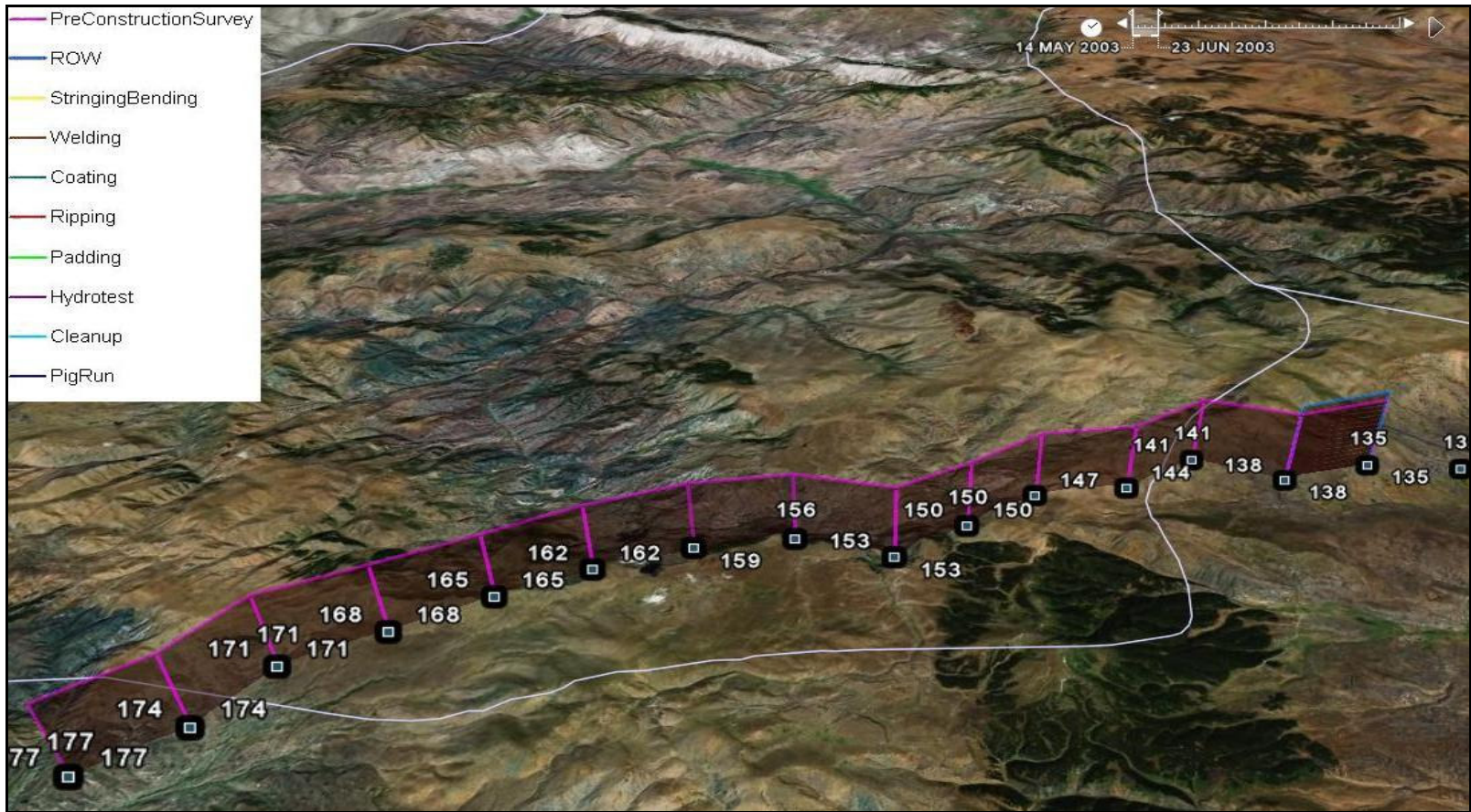
Figure 4.6: ROW Grading was started on June 23, 2003
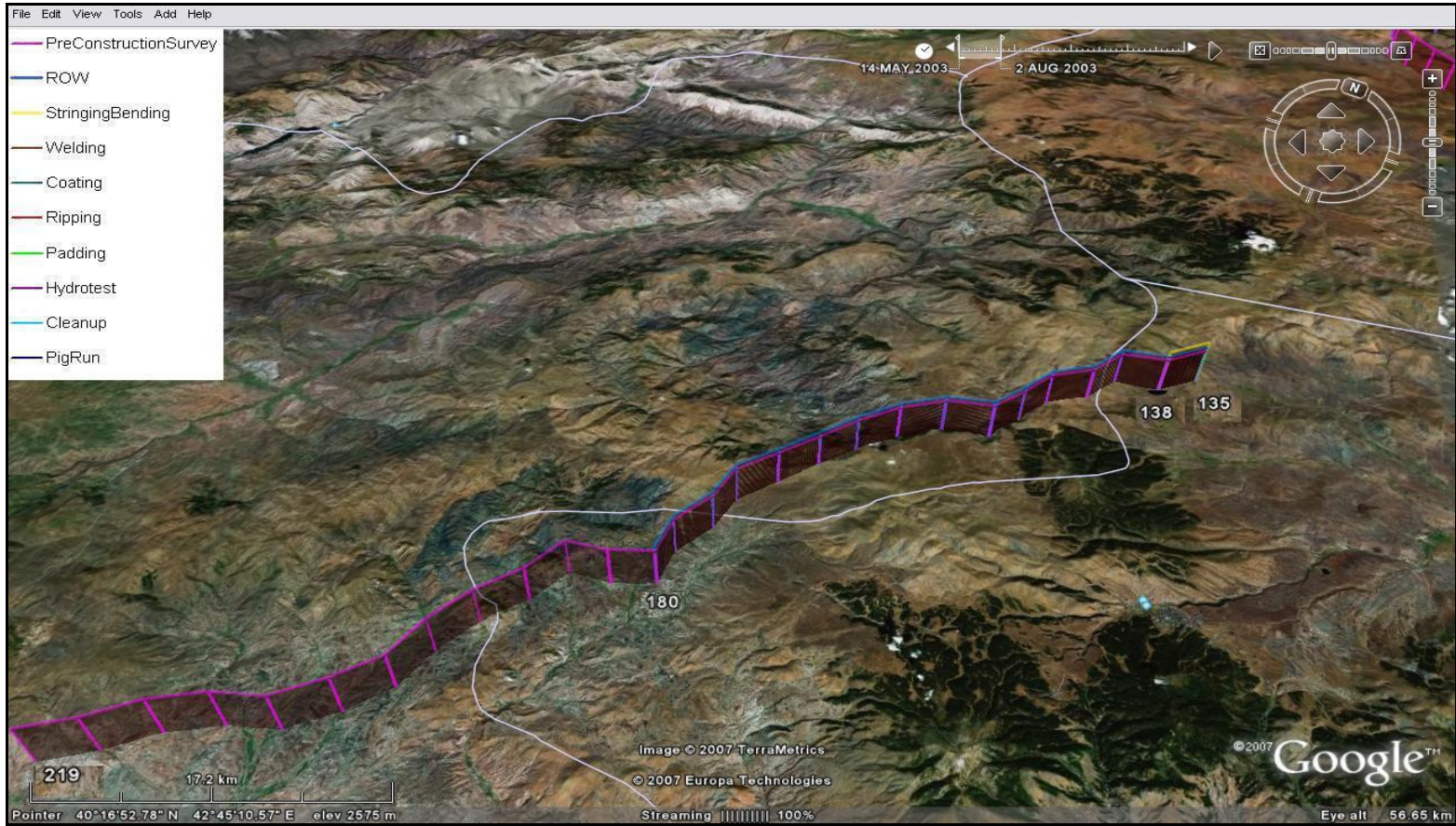
Figure 4.7: Stringing- Bending was started on August 2, 2003

Figure 4.8: Progress on August 21, 2003

Figure 4.9: Progress on December 2, 2003
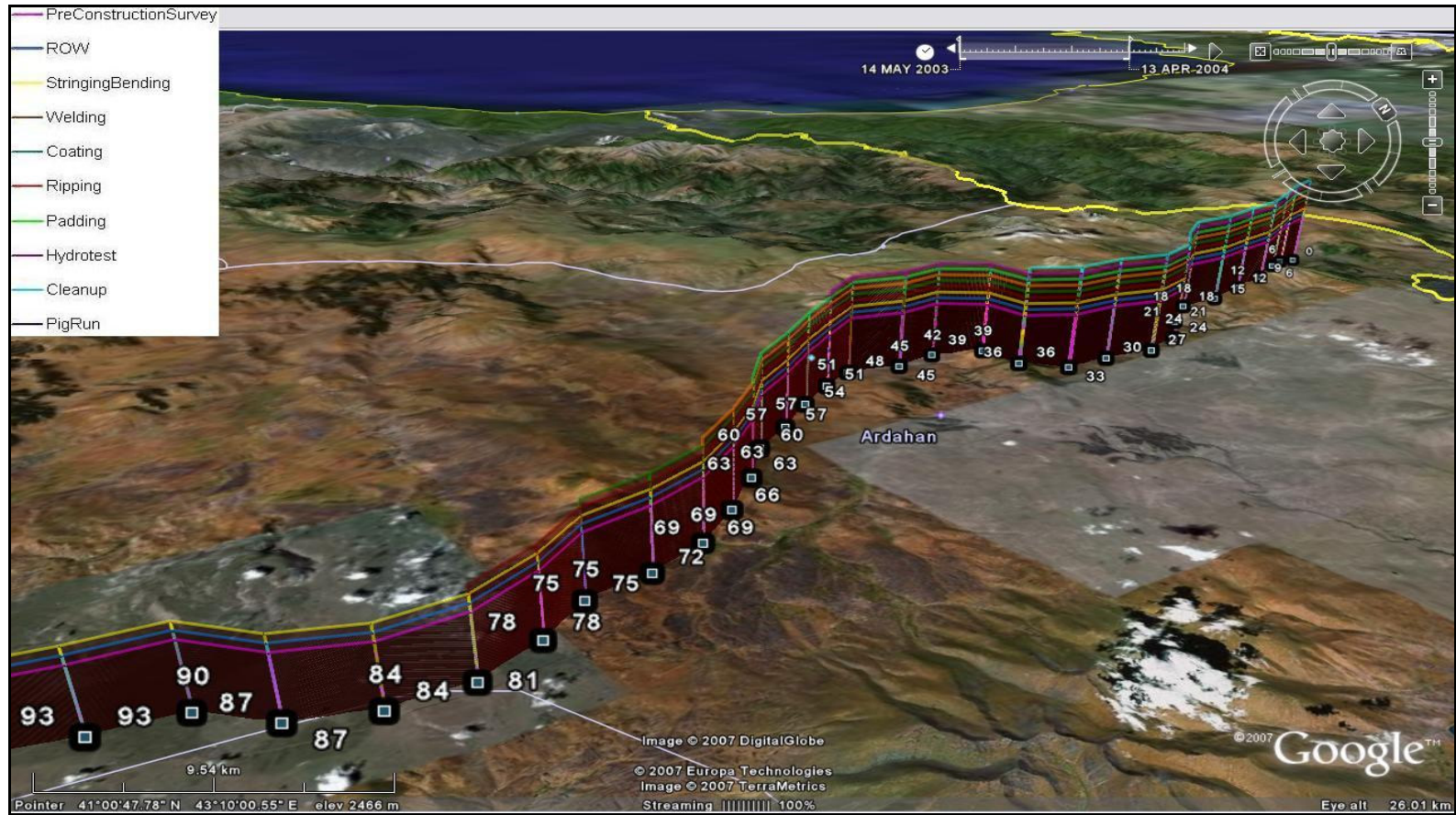
Figure 4.10: Progress on April 14, 2003

4.3.3 Results

From Figure 4.5 to Figure 4.10, it can be seen that same milestones can be identified as it was in LOB method. Different from LOB method, station kilometers and line of sight of pipeline can be visualized in 3-D environment together with time frame integration. Since it is visual, GPS/GIS based method can be understood by owners and decision makers more easily. Moreover, visualization of the schedule may help planners to identify potential delays. An example may be river crossings and road crossings. If these potential obstacles can be seen visually with this technique, schedule could be updated so as to allow for a decrease in rate of work progress for those areas. On the other, with traditional method, river and road crossings can only be seen with preconstruction survey activity by experiencing the site conditions. Also with time integration the whole planned status of the project could be seen like a movie which would improve visualization, understanding and control of the schedule.

4.4   Progress Control Using GPS/GIS Based LOB Method

In this section, a scenario which is behind the planned schedule, were generated in order to show that with GPS/GIS based LOB method, progress of each activity can be controlled and it can be followed by project participants and owners more easily than LOB method.

4.4.1   As-built   Schedule   Scenario: Behind   the   Planned   Schedule

As can be seen from Figure 4.11, R.O.W activity is assumed to progress 600 m/day whereas in real schedule it was 1000m/day. With LOB method, it is not

easy to show on which locations activity is late. A horizontal line has to be drawn on the date of progress and graph has to be read. Moreover, in order to measure progress, every time a graph like Figure 4.11 has to be drawn. On the other hand, with the GPS/GIS based LOB method, with figure 4.12 to 4.13, it can easily be followed that, ROW activity is late. As soon as GPS data and date information is gathered, model can be created automatically by GIS software.
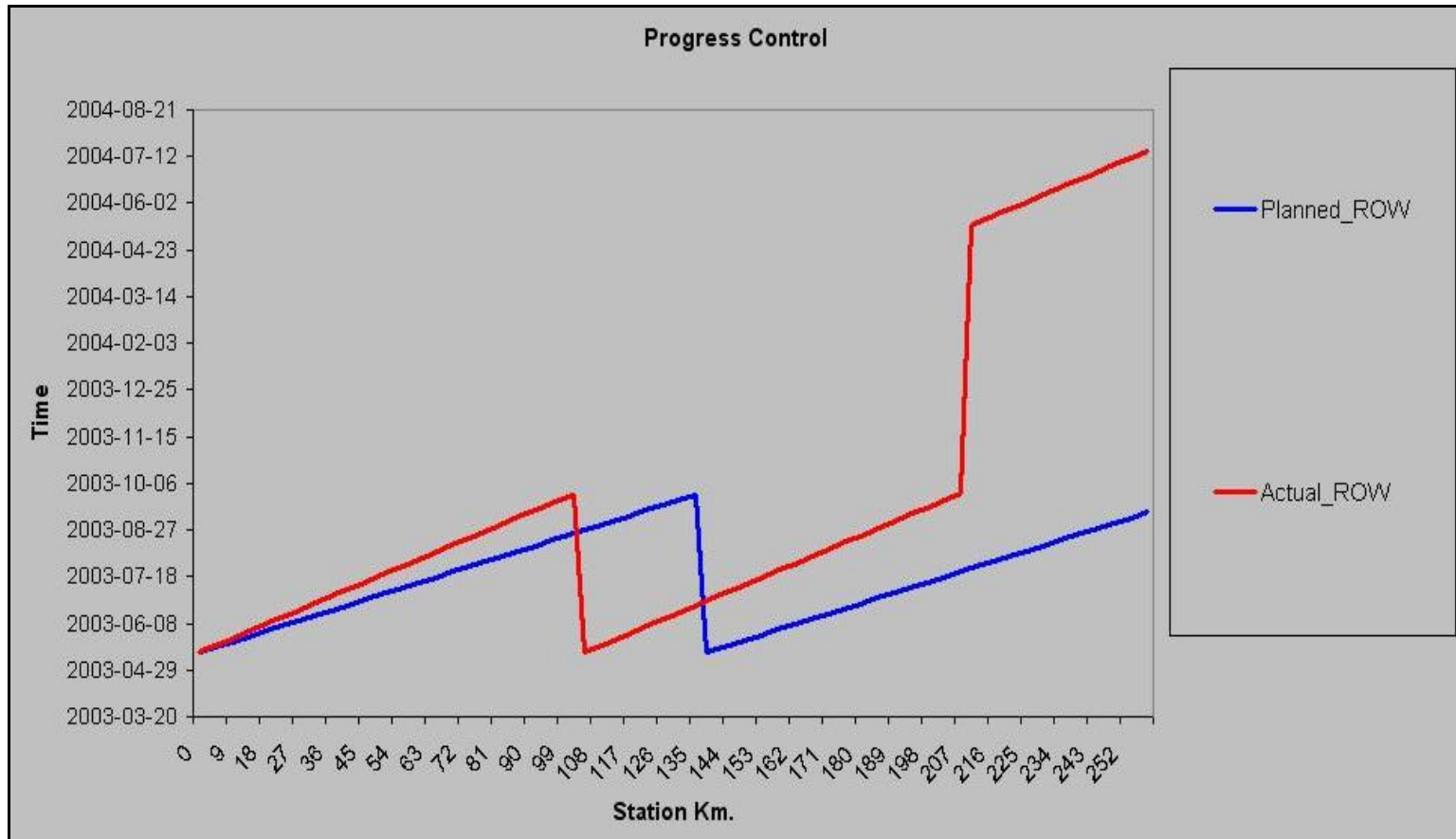
Figure 4.11: Progress of ROW Activity with LOB Method
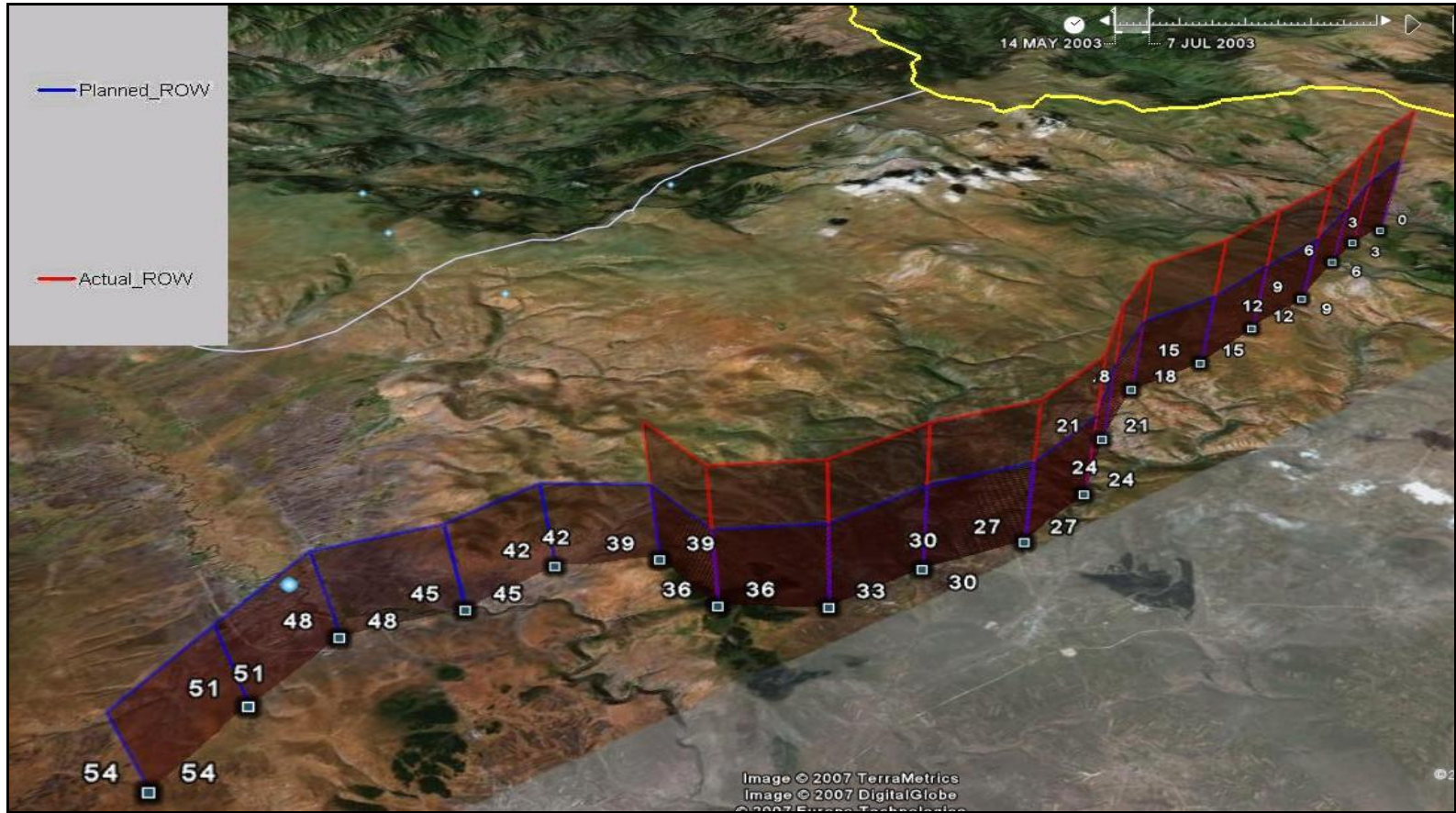
Figure 4.12: Progress of ROW on 7 July, 2003
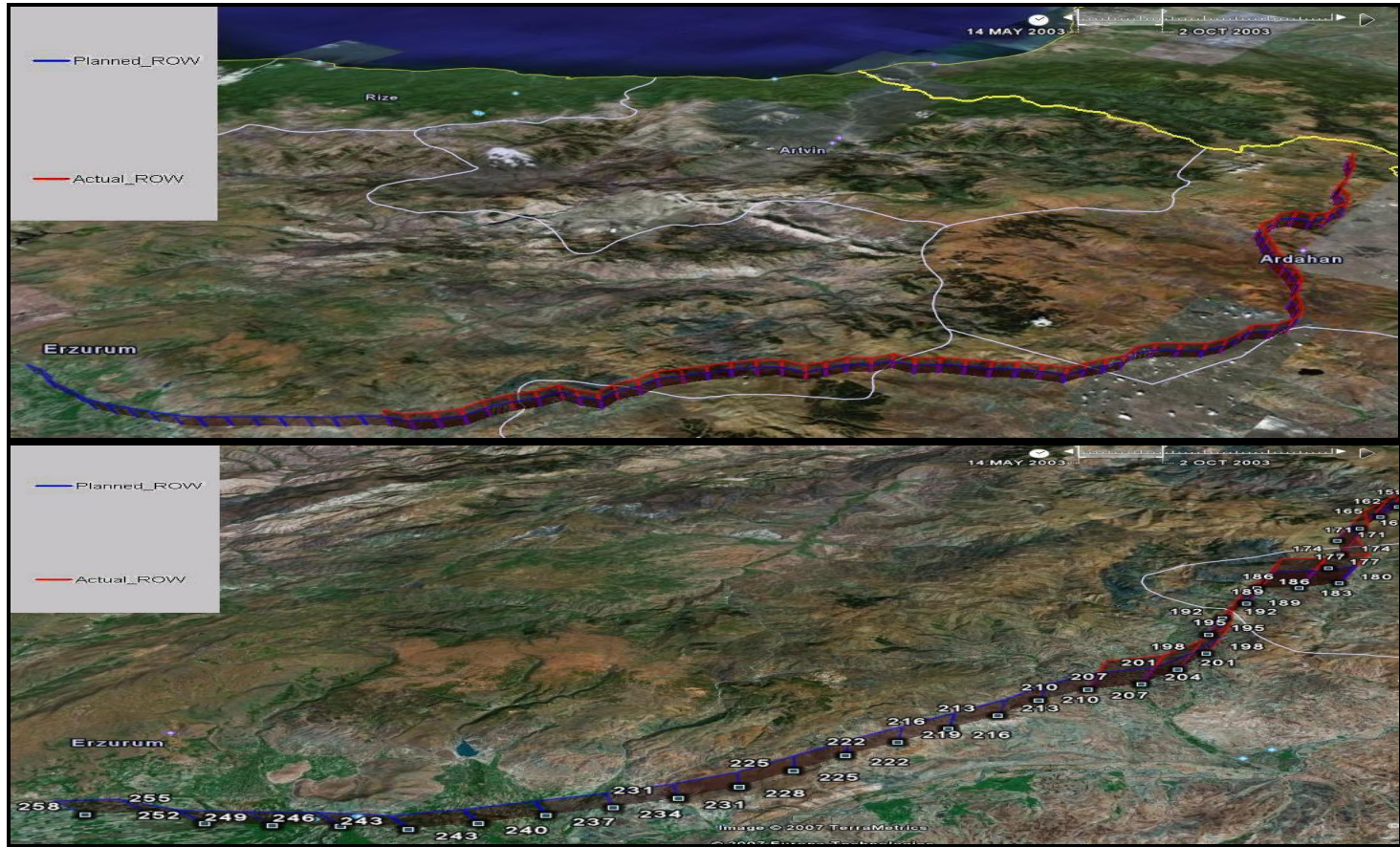
Figure 4.13: Progress of ROW on 2 October, 2003

4.5 Summary of Findings

- With traditional LOB method, location information is only envisioned in the mind of planning engineer. On the other hand, with GPS/GIS based LOB method, spatial information can be visualized also by project participants, owners or decision makers.

- Any physical obstacle, like river and road crossings, can be seen from 3-D environment so that planning could be further improved.

- Integration of time coordinate to GPS/GIS based system improves understanding and control of the schedule.

- Since schedule information is visual, it can easily be published through web site which may improve the control process.

- Real time progress control is possible with GPS/GIS based LOB method.

GPS/GIS based LOB method was applied to a real pipeline project in this chapter. Results revealed that this method bring many advantages existing methods. These advantages are mainly about its visual demonstration capability. By this kind of representation, schedule can be followed easily by project participants and owners. Since this is a prototype research, this method can be improved with further researches. Potential improvements to this method will be covered in the next chapter.

CHAPTER 5

CONCLUSIONS

Proposed GPS/GIS based LOB method is a prototype method which requires further improvements. Although it is not a complete scheduling tool yet, it is important to examine advantages and disadvantages of it over existing methods.

Advantages of this method over other methods are;

- It is to understand the outputs compared to CPM networks and LOB method because of the visual representation of schedule. It does not require technical knowledge to follow the schedule.

- Schedule information can be published via web easily, which further improves coordination between project participants.

- Because the tasks are all visible, participants can identify their responsibilities easily. This would result better acceptance of schedule among project participants.

- Real time updates of schedule are possible with this method. It requires only GPS data and progress information of the activities.

- Known LOB method does not visually represent the project versus time. On the other hand, GPS/GIS based LOB method can display project information with time frame integration.

- With GPS/GIS based LOB method, progress control can be done faster than traditional LOB method. As soon as GPS and date information is gathered, GIS software automatically generates the schedule.

Disadvantages of this method over other methods are;

- Since it is a visual representation of activity progresses at this stage, network scheduling is not possible yet

- As activity number increases, representation of activity progresses may be difficult.

Proposed GPS/GIS based LOB balancing method possesses visual advantages over existing planning and control methods for repetitive projects. It can be improved to become a better scheduling tool. The following items may be utilized to improve the current status of the system.

- Better GIS software can be used to model the whole progress. Time frame integration can be done with the help of other software which may improve the demonstration process.

- A better map can be used which has better resolution and which includes several physical details to improve both planning and control stages.

- Demonstration of as-planned schedule and as-built schedule can be synchronized to have an integrated control system.

- Distance between points can be reduced so as to have a better model of the progress. Even daily progress can be seen if distance between points is reduced less than 1 km.

- Network scheduling could be included to determine the critical path and activity floats.

- Resource loading and leveling options could be included in the system.

As a summary, a GPS/GIS based LOB method was developed for planning and control of repetitive construction projects. The method was implemented to a pipeline project. The main advantage of the system is improved visualization which is achieved by the integration of the GPS/GIS information to activities together with time coordinates. Improved visualization leads to better understanding and control of the schedule.

The method developed is a prototype system at this stage which can be used to visualize the schedule. Further developments are needed so that it becomes a complete scheduling tool. However, with the prototype system potential advantages of GPS/GIS based LOB method was demonstrated which could lead

to development of a full GPS/GIS based scheduling tool for repetitive construction projects.

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APPENDIX A

PROGRAM CODES

```csharp
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Text;
using System.Windows.Forms;
using System.Xml;
using System.Data.OleDb;

namespace GoogleEarthKML
{
        public partial class GoogleEarthKML : Form
        {
                private static String fileName = null;
                private static String kmlFileName = null;
                private XmlTextWriter writer = null;
                private Color[] colors = null;
                private Color[] PolyColors = null;
                private Color defaultColor = Color.FromArgb(125, 160, 0, 0);

                public GoogleEarthKML()
                {
                        InitializeComponent();
                }

                private void BrowseFile_Click(object sender, EventArgs e)
                {
                        openFileDialog1.FileName = "*.xls";
                        if (openFileDialog1.ShowDialog() == DialogResult.OK)
                        {
                                fileName = openFileDialog1.FileName;
```

```csharp
                            //MessageBox.Show(fileName);
                            kmlFileName = fileName.Substring(0,
fileName.LastIndexOf("\\") + 1) + "furkan1.kml";
                            kmlFileName = kmlFileName.Replace("\\\\", "\\");
                            //MessageBox.Show(kmlFileName);
                            readActivities();
                            groupBox1.Enabled = true;
                            //for(int i=0; i<ComboBoxActivities.Items.Count)
                            ComboBoxAltitudeMode.SelectedIndex = 0;
                    }
                    else
                            groupBox1.Enabled = false;
            }

            private void selectColor_Click(object sender, EventArgs e)
            {
                    colorDialog.FullOpen = true;
                    if (colorDialog.ShowDialog() == DialogResult.OK)
                    {
                            Color color = colorDialog.Color;
                            LabelColor.BackColor = color;
                            LabelColor.Text = color.ToArgb().ToString("X");
                            colors[ComboBoxActivities.SelectedIndex] = color;
                    }
            }

            private void selectPolyColor_Click(object sender, EventArgs e)
            {
                    PolyColorDialog.FullOpen = true;
                    if (PolyColorDialog.ShowDialog() == DialogResult.OK)
                    {
                            Color color = PolyColorDialog.Color;
                            LabelPolyColor.BackColor = color;
                            LabelPolyColor.Text =
color.ToArgb().ToString("X");
                            PolyColors[ComboBoxActivities.SelectedIndex] =
color;
                    }
            }
```

```
private void initializeXmlTextWriter()
{
        writer.Namespaces = true;
        writer.Formatting = Formatting.Indented;
        writer.Indentation = 4;
        writer.QuoteChar = '\"';
}

private void WriteDocument(XmlWriter writer, DataTable dt,
String endDate, String activity, String color, String PolyColor, String Z)
{
        int i = 0;
        try
        {
                //writer.WriteStartDocument();
                //writer.WriteStartElement("", "kml",
"http://earth.google.com/kml/2.1");
                //writer.WriteStartElement("Folder");
                for (; i < dt.Rows.Count - 1; i++)
                {
                        writer.WriteStartElement("Placemark");
                        writer.WriteElementString("visibility",
TextBoxVisibility.Text);

                        writer.WriteStartElement("Style");
                        writer.WriteStartElement("LineStyle");
                        writer.WriteElementString("color", color);
                        writer.WriteElementString("width",
TextBoxWidth.Text);

                        writer.WriteEndElement();
                        writer.WriteStartElement("PolyStyle");
                        writer.WriteElementString("color",
PolyColor);

                        writer.WriteEndElement();
                        writer.WriteEndElement();
                        writer.WriteElementString("tessellate",
TextBoxTessellate.Text);

                        writer.WriteStartElement("LineString");
```

```csharp
                                        writer.WriteElementString("extrude",
TextBoxExtrude.Text);
                                        writer.WriteElementString("altitudeMode",
ComboBoxAltitudeMode.Text);
                                        if (Z == null)
                                                Z =
dt.Rows[i]["Z"].ToString().Replace(',', '.');
                                        String coordinates = " " +
dt.Rows[i]["E"].ToString().Replace(',', '.') + ", " +

    dt.Rows[i]["N"].ToString().Replace(',', '.') + ", " +

    Z + " " +

    dt.Rows[i + 1]["E"].ToString().Replace(',', '.') + ", " +

    dt.Rows[i + 1]["N"].ToString().Replace(',', '.') + ", " +

    Z + " ";
                                        writer.WriteElementString("coordinates",
coordinates);
                                        writer.WriteEndElement();
                                        writer.WriteStartElement("TimeSpan");
                                        String beginDate =
Convert.ToDateTime(dt.Rows[i + 1][activity]).ToString("yyyy-MM-dd");
                                        writer.WriteElementString("begin",
beginDate);
                                        writer.WriteElementString("end", endDate);
                                        writer.WriteEndElement();
                                        writer.WriteEndElement();
                            }
                            //writer.WriteEndElement();
                            //writer.WriteEndDocument();
                    }
                    catch (Exception ex)
                    {
                            MessageBox.Show(ex.Message + " "+ i);
                    }
            }
```

```csharp
private void WriteDocument2(XmlWriter writer, DataTable dt,
String endDate, String activity, String color, String PolyColor, String Z)
        {
                int i = 0;
                try
                {
                        //writer.WriteStartDocument();
                        //writer.WriteStartElement("", "kml",
"http://earth.google.com/kml/2.1");
                        //writer.WriteStartElement("Folder");
                        for (; i < dt.Rows.Count; i++)
                        {
                                writer.WriteStartElement("Placemark");
                                if (i + 1 == dt.Rows.Count)
                                {
                                        int x = 0;
                                        x++;
                                }
                                writer.WriteElementString("name",
dt.Rows[i]["Name"].ToString());
                                writer.WriteElementString("styleUrl",
"#sgrillo1");

                                writer.WriteStartElement("Point");
                                if (Z == null)
                                        Z =
dt.Rows[i]["Z"].ToString().Replace(',', '.');
                                String coordinates =
dt.Rows[i]["E"].ToString().Replace(',', '.') + "," +

        dt.Rows[i]["N"].ToString().Replace(',', '.') + "," +

        Z;
                                writer.WriteElementString("coordinates",
coordinates);
                                writer.WriteEndElement();
                                writer.WriteEndElement();
                        }
                        //writer.WriteEndElement();
```
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```csharp
                            //writer.WriteEndDocument();
                }
                catch (Exception ex)
                {
                        MessageBox.Show(ex.Message + " " + i);
                }
        }

        private String readActivities()
        {
                try
                {
                        OleDbConnection con = new
OleDbConnection(@"Provider=Microsoft.JetOLEDB.4.0;Data Source=" +
fileName + ";Extended Properties=Excel 8.0");
                        OleDbDataAdapter da = new
OleDbDataAdapter("SELECT TOP 1 * FROM COORDINATE_TABLE", con);
                        DataTable dt = new DataTable();
                        da.Fill(dt);
                        if (dt != null)
                        {
                                colors = new Color[dt.Columns.Count - 4 +
1];

                                PolyColors = new Color[dt.Columns.Count -
4 + 1];

                                colors[dt.Columns.Count - 4] = defaultColor;
                                PolyColors[dt.Columns.Count - 4] =
defaultColor;

                                for (int i = 4; i < dt.Columns.Count; i++)
                                {

        //MessageBox.Show(dt.Columns[i].ToString());

        ComboBoxActivities.Items.Add(dt.Columns[i].ToString());
                                        colors[i - 4] = defaultColor;
                                        PolyColors[i - 4] = defaultColor;
                                }
                                ComboBoxActivities.Items.Add("All");
                                ComboBoxActivities.SelectedIndex = 0;
                                77
```

```csharp
                                                return null;
                                        }
                                        else
                                        {
                                                MessageBox.Show("The table does not have
any column..");

                                                return null;
                                        }
                                }
                                catch (Exception ex)
                                {
                                        MessageBox.Show(ex.Message);
                                        return null;
                                }
                        }

                private String readMaxDate(String activity)
                {
                        try
                        {
                                OleDbConnection con = new
OleDbConnection(@"Provider=Microsoft.JetOLEDB.4.0;Data Source=" +
fileName + ";Extended Properties=Excel 8.0");
                                OleDbDataAdapter da = new
OleDbDataAdapter("SELECT Max(" + activity + ") FROM
COORDINATE_TABLE", con);
                                DataTable dt = new DataTable();
                                da.Fill(dt);
                                if (dt != null && dt.Rows.Count > 0)
                                        return
Convert.ToDateTime(dt.Rows[0][0]).ToString("yyyy-MM-dd");
                                else
                                {
                                        MessageBox.Show("The table does not have
any row");

                                        return null;
                                }
                        }
                        catch (Exception ex)
```

```
                    {
                            MessageBox.Show(ex.Message);
                            return null;
                    }
            }

            private DataTable readExcel()
            {
                    try
                    {
                            OleDbConnection con = new
OleDbConnection(@"Provider=Microsoft.JetOLEDB.4.0;Data Source=" +
fileName + ";Extended Properties=Excel 8.0");
                            OleDbDataAdapter da = new
OleDbDataAdapter("SELECT * FROM COORDINATE_TABLE", con);
                            DataTable dt = new DataTable();
                            da.Fill(dt);
                            if (dt != null && dt.Rows.Count > 0)
                                    return dt;
                            else
                            {
                                    MessageBox.Show("The table does not have
any row..");
                                    return null;
                            }
                    }
                    catch (Exception ex)
                    {
                            MessageBox.Show(ex.Message);
                            return null;
                    }
            }

            private void createKml_Click(object sender, EventArgs e)
            {
                    kmlFileName = kmlFileName.Replace("2.", "1.");
                    String width = TextBoxWidth.Text;
                    String tessellate = TextBoxTessellate.Text;
                    String color = null;
```

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```
String PolyColor = null;
String endDate = DateTime.MinValue.ToString("yyyy-
MM-dd");

DataTable dt = null;
String temp = null;
dt = readExcel();
if (dt != null)
{
        writer = new XmlTextWriter(kmlFileName,
Encoding.UTF8);
        initializeXmlTextWriter();

        writer.WriteStartDocument();
        writer.WriteStartElement("", "kml",
"http://earth.google.com/kml/2.1");
        writer.WriteStartElement("Folder");
        //writer.WriteStartElement("Placemark");

        if (ComboBoxActivities.SelectedIndex !=
ComboBoxActivities.Items.Count - 1)
        {
                endDate =
readMaxDate(ComboBoxActivities.Text);
                color =
colors[ComboBoxActivities.SelectedIndex].ToArgb().ToString("X");
                PolyColor =
PolyColors[ComboBoxActivities.SelectedIndex].ToArgb().ToString("X");
                WriteDocument(writer, dt, endDate,
ComboBoxActivities.SelectedItem.ToString(), color, PolyColor, null);
        }
        else if (ComboBoxActivities.SelectedIndex ==
ComboBoxActivities.Items.Count - 1)
        {
                for (int i = 0; i <
ComboBoxActivities.SelectedIndex; i++)
                {
                        temp =
readMaxDate(ComboBoxActivities.Items[i].ToString());
```

```csharp
                                    if (Convert.ToDateTime(temp) >
Convert.ToDateTime(endDate))

                                        endDate = temp;
                            }

                            for (int i = 0; i <
ComboBoxActivities.SelectedIndex; i++)
                            {
                                //endDate =
readMaxDate(ComboBoxActivities.Items[i].ToString());
                                if (!checkBoxColor.Checked)
                                    color =
colors[i].ToArgb().ToString("X");
                                else
                                    color = colors[colors.Length -
1].ToArgb().ToString("X");


                                if (!checkBoxPolyColor.Checked)
                                    PolyColor =
PolyColors[i].ToArgb().ToString("X");
                                else
                                    PolyColor =
PolyColors[PolyColors.Length - 1].ToArgb().ToString("X");


                                WriteDocument(writer, dt, endDate,
ComboBoxActivities.Items[i].ToString(), color, PolyColor,
Convert.ToString(Convert.ToInt32(TextBoxZ.Text) + i *
Convert.ToInt32(TextBoxDiff.Text)));
                            }
                        }
                        //writer.WriteEndElement();
                        writer.WriteEndElement();
                        writer.WriteEndElement();
                        writer.WriteEndDocument();

                        writer.Flush();
                        writer.Close();
                        MessageBox.Show("OK!");
                    }
```

```csharp
                }

                private void ComboBoxActivities_SelectedIndexChanged(object
sender, EventArgs e)
                {
                    LabelColor.BackColor =
colors[ComboBoxActivities.SelectedIndex];
                    LabelColor.Text =
colors[ComboBoxActivities.SelectedIndex].ToArgb().ToString("X");
                    LabelPolyColor.BackColor =
PolyColors[ComboBoxActivities.SelectedIndex];
                    LabelPolyColor.Text =
PolyColors[ComboBoxActivities.SelectedIndex].ToArgb().ToString("X");
                    if (ComboBoxActivities.SelectedIndex ==
ComboBoxActivities.Items.Count - 1)
                    {
                        checkBoxColor.Visible = true;
                        checkBoxPolyColor.Visible = true;
                    }
                    else
                    {
                        checkBoxColor.Visible = false;
                        checkBoxPolyColor.Visible = false;
                    }
                }

            private void createWithName_Click(object sender, EventArgs e)
            {
                kmlFileName = kmlFileName.Replace("1.", "2.");
                String width = TextBoxWidth.Text;
                String tessellate = TextBoxTessellate.Text;
                String color = null;
                String PolyColor = null;
                String endDate = DateTime.MinValue.ToString("yyyy-
MM-dd");
                DataTable dt = null;
                String temp = null;
                dt = readExcel();
                if (dt != null)
```

```
                    {
                            writer = new XmlTextWriter(kmlFileName,
Encoding.UTF8);
                            initializeXmlTextWriter();

                            writer.WriteStartDocument();
                            writer.WriteStartElement("", "kml",
"http://earth.google.com/kml/2.1");
                            writer.WriteStartElement("Document");
                            writer.WriteElementString("name", "Station Km");
                            writer.WriteStartElement("Style");
                            writer.WriteStartAttribute("id");
                            writer.WriteValue("sgrillo1");
                            writer.WriteEndAttribute();
                            writer.WriteStartElement("IconStyle");
                            writer.WriteStartElement("Icon");
                            writer.WriteElementString("href",
"http://maps.google.com/mapfiles/kml/pal4/icon24.png");
                            writer.WriteEndElement();
                            writer.WriteEndElement();
                            writer.WriteStartElement("LabelStyle");
                            writer.WriteEndElement();
                            writer.WriteEndElement();
                            writer.WriteStartElement("Folder");
                            writer.WriteElementString("name", "Names");

                            if (ComboBoxActivities.SelectedIndex !=
ComboBoxActivities.Items.Count - 1)
                            {
                                    endDate =
readMaxDate(ComboBoxActivities.Text);
                                    color =
colors[ComboBoxActivities.SelectedIndex].ToArgb().ToString("X");
                                    PolyColor =
PolyColors[ComboBoxActivities.SelectedIndex].ToArgb().ToString("X");
                                    WriteDocument2(writer, dt, endDate,
ComboBoxActivities.SelectedItem.ToString(), color, PolyColor, null);
                            }
```

```csharp
                else if (ComboBoxActivities.SelectedIndex ==
ComboBoxActivities.Items.Count - 1)
                {
                    for (int i = 0; i <
ComboBoxActivities.SelectedIndex; i++)
                    {
                        temp =
readMaxDate(ComboBoxActivities.Items[i].ToString());
                        if (Convert.ToDateTime(temp) >
Convert.ToDateTime(endDate))
                            endDate = temp;
                    }

                    for (int i = 0; i <
ComboBoxActivities.SelectedIndex; i++)
                    {
                        //endDate =
readMaxDate(ComboBoxActivities.Items[i].ToString());
                        if (!checkBoxColor.Checked)
                            color =
colors[i].ToArgb().ToString("X");
                        else
                            color = colors[colors.Length -
1].ToArgb().ToString("X");

                        if (!checkBoxPolyColor.Checked)
                            PolyColor =
PolyColors[i].ToArgb().ToString("X");
                        else
                            PolyColor =
PolyColors[PolyColors.Length - 1].ToArgb().ToString("X");

                        WriteDocument2(writer, dt, endDate,
ComboBoxActivities.Items[i].ToString(), color, PolyColor,
Convert.ToString(Convert.ToInt32(TextBoxZ.Text) + i *
Convert.ToInt32(TextBoxDiff.Text)));
                    }
                }
                writer.WriteEndElement();
```

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```
                        writer.WriteEndElement();
                        writer.WriteEndElement();
                        writer.WriteEndDocument();

                        writer.Flush();
                        writer.Close();
                        MessageBox.Show("OK!");
                }
            }

        }
    }
```