The Islamic University of Gaza

High Education Deanship

Faculty of Engineering
Civil Engineering Department

Engineering Projects Management

الجامعة الإسلامية – غزة

عمادة الدراسات العليا

كلية الهندسة – قسم الهندسة المدنية

إدارة المشروعات الهندسية

Utilizing GIS for Cost Control in Infrastructure Projects

استخدام نظم المعلومات الجغرافية للتحكم في تكاليف مشاريع البنية التحتية

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A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in Civil Engineering

1435هـ **2014م**

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Abstract

Cost control is a basic issue that has its increased importance due to competitive nature of engineering projects. Each party of any project concerns on achieving his goals by least cost in order to make final sufficient benefits. New computerized systems have been developed very efficiently to offer the most capabilities for more perfect and reliable work. This research concerns on how to utilize GIS great capabilities for cost control in infrastructure projects, and how to improve the applying of cost control processes to get more control. To achieve this aim, interviews with specialists are performed, several issues of cost control processes have been discussed based on comprehensive literature review and good experience.

Unfortunately, Cost control processes are applied very poorly in Gaza; So, experts emphasize on improving cost control in projects. Conceptual model of cost control has been built and discussed with experts. The main concept is to divide the project to three control levels: element "task" level as data collection level, contractual item level as main cost control level, and finally, project level as summary level. Cost control processes deal with "variances"; So, this research focuses on cost control elements as cost variance (CV), cost performance index (CPI), estimation to completion (ETC), estimation at completion (EAC), progress ratio, and forecasting variances between contract and what planned to perform.

A computerized system based on GIS has been established and applied on a case study to explore its capabilities. GIS capabilities give more accurate results, early quantity surveying, lots of tabulated and graphical information, many visual outputs, statistical indicators, rather than easy inquiries and selection methods. The research recommends to join time schedule to the system, and use this open environment for more developing in order to produce integrated computerized extension that can be used very easy for reliable decision-making.

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الملخص

يعد ضبط التكلفة مسألة تكتسب أهمية متزايدة نظرا للطبيعة التنافسية للمشاريع الهندسية، حيث يسعى كل طرف في أي مشروع لتحقيق أهدافه بأقل التكاليف من أجل تحقيق أرباح نهائية مجزئة، وقد تم تطوير أنظمة حاسوبية بكفاءة عالية تقدم أقصى الإمكانات من أجل إنجاز العمل بمزيد من الإتقان والثقة. يركز هذا البحث على كيفية تطويع نظم المعلومات الجغرافية بإمكاناته الكبيرة في ضبط التكلفة في مشاريع البنية التحتية، وكيف يمكن تطوير وتحسين ممارسة عمليات ضبط التكلفة للحصول على مزيد من الضبط والتحكم، ولتحقيق هذا الهدف، تم إجراء العديد من المقابلات مع المختصين، وقد نوقشت عدة قضايا متعلقة بعمليات ضبط التكلفة اعتمادا على الخلفية العلمية المستقاة من الدراسات السابقة، كذلك من الخبرة الميدانية في المشاريع.

من المؤسف أن تطبيق عمليات ضبط التكلفة في غزة يتم بصورة ضعيفة؛ وعليه فقد أكد الخبراء على ضرورة تطوير ذلك في المشاريع. تم بناء نموذج لطريقة ضبط التكلفة ومناقشة الفكرة مع الخبراء. إن المفهوم الأساس في ذلك النموذج هو تقسيم المشروع إلى ثلاث مستويات من الضبط: مستوى العنصر "المهمة" كمستوى لجمع البيانات، مستوى البند التعاقدي كمستوى أساس في ضبط التكلفة، وأخيرا مستوى المشروع ككل كمستوى ملخص نهائي. عمليات ضبط التكلفة تتعامل أساسا مع "التباينات"، وعليه فإن هذا البحث ركز على عناصر ضبط التكلفة مثل فرق التكلفة، مؤشر فعالية التكلفة، التقديرات لنهاية الإنجاز، التقديرات عند نهاية الإنجاز، نسبة الإنجاز، وتباينات التوقع المستقبلي ما بين المتعاقد عليه وبين الخطط التنفيذية.

تم تأسيس نظام محوسب يعتمد على نظم المعلومات الجغرافية وتطبيقه على حالة دراسية لاستكشاف قدرات النظام. إن إمكانات نظم المعلومات الجغرافية أعطت نتائج أكثر دقة، حساب كميات مبكر، العديد من المعلومات المجدولة والرسومية، الكثير من المخرجات البصرية، مؤشرات إحصائية، علاوة على الاستعلامات وطرق اختيار العناصر بسهولة. يوصي البحث بربط الجدول الزمني بالنظام، واستخدام هذه البيئة المفتوحة لمزيد من التطوير من أجل إنتاج منظومة حاسوبية متكاملة يمكن استخدامها بسهولة لاتخاذ القرار بثقة.

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Dedication

إلى كل شخص ساعدني...

إلى الأشخاص الذين منحوني دعما معنويا خاصا...

وأيضا،

إلى جميع الضحايا الذين يعانون من الظلم والاضطهاد...

أهدي هذا العمل.

TO EACH PERSON WHO SUPPORTS ME...

TO PERSONS WHO GIVE ME SPECIAL MORALE SUPPORT...

ALSO,

TO ALL VICTIMS WHO SUFFER FROM INJUSTICE AND PERSECUTION...

I DEDICATE THIS WORK.

المنارة للاستشارات
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Table of Contents

المنارة للاستشارات

www.manaraa.com

المنارة للاستشارات

www.manaraa.com

المنارة للاستشارات

www.manaraa.com

List of Figures

المنارة للاستشارات
www.manaraa.com

List of Tables

المنارة للاستشارات
www.manaraa.com

List of Abbreviations

AC	Actual Cost
BOQ	Bill Of Quantities
CAD	Computer Aided Design
CPI	Cost Performance Index
CV	Cost Variance
DEM	Digital Elevation Model
EAC	Estimation At Completion
ESRI	Environmental Systems Research Institute
ETC	Estimated To Complete
EV	Earned Value
GDP	Gross domestic product
GIS	Geographic Information Systems
GPS	Global Positioning System
GRS80	Geodetic Reference System 1980
ITM	Israeli Transverse Mercator
MUIM	Ministry of Urban Infrastructure Management (Australia)
M&S	Modelling and Simulation
OECD	Organization for Economic Co-operation and Development
TIN	Triangulated Irregular Network
TOC	Table Of Content
VPF	Vector Product Format
WBS	Work Breakdown Structure

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Chapter One

Introduction

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1.1 Background

Cost, Time, and quality indicators can measure the performance of construction projects. Cost control is an important factor of profitable projects. It is a serious effort along the project to manage tasks according to realistic plans to complete the project successfully. (Moura *et al*., 2007).

The importance of cost and time control is widely recognized by construction professionals in practice. It is related to the fact of the conflict between making enough profit and competitive nature of construction industry. It is a critical balance between needs and abilities. Control process consists of actions taken in response to information, then, it has necessary to get true information to do effective response. (Olawale & Sun, 2010), (Hinze, 2008).

1.2 Problem Statement

It is really that using of computerized methods can make the work more accurate, but working with multiple windows at the same time is not comfortable. Moreover, several software packages are needed to perform simple routine tasks; Thus, developing powerful computerized system becomes very necessary for these reasons:

- The need for increasing capabilities to do tasks those are more complex.
- Using several software packages cost more money.
- Differences of software versions often make confuses and data loss.
- It is a global trend to "paperless management" to reduce need for paper for environmental and economic reasons.

The developed system aims to utilize Geographic Information Systems (GIS) capabilities to perform cost control. Modelling of physical components in computer by geometric features that combined with database engine is more effective for control and documenting, GIS tools can meet these needs easily. The vital link between spatial features and its database is the most important advantage of GIS. Therefore, geo-processing tools can be recruited for constructions as geography and management processes can be performed more easily.

1.3 Goal and Objectives

The main goal is to improve cost control process for infrastructure projects in Gaza.

Objectives can be considered as:

1) Investigate the applying of cost control in Gaza Strip.
2) Identify the basic indicators of cost control process.
3) Build conceptual model and establish computerized system.

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1.4 Research Methodology

The first step of methodology is getting basic knowledge about the topic; this can be achieved by two ways: literature review and interviews. Literature review can supply basic information about previous experiences around the world. Interviews can help to investigate opinions about the application of cost control and common difficulties, then, what kind of management that can be more effective.

The second step is to establish the basic concepts and flowcharts of the developed system. Review the logical steps, select the most appropriate software; then, apply these concepts on computer to establish the system. In addition, it is useful to use some capabilities of geo-processing tools, which have friendly user interface and work within the basic software, this is an important advantage.

Finally, is to perform a case study to test the system on a real previous project with a case study application. Testing any system is an important step that consumes a lot of time and effort. The selected project has to be a real infrastructure project and GIS capabilities can work very easy with infrastructure projects.

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1.5 Research Structure

In this research, Cost control processes have to be studied; In addition to apply these tools has to be discussed with experts in order to build clear background about topic. Thus, Chapter One introduce basic background of the idea with brief methodology of research; Chapter Two show basic literature review about other researches and some applications. This research focuses on cost control concepts with GIS capabilities, and how can GIS be used as a powerful tool.

Chapter Three is the main chapter of this research that offers comprehensive idea with detailed methodology, it offers the basic conceptual model in order to construct the developed system. Also, the developed system is constructed by GIS software. The developed model concepts are used step by step in order to build compatible system that can give useful results.

Chapter Four illustrates these concepts and applications by a case study, an infrastructure project in Gaza City is selected to apply the developed system to get results and show how the developed system work; This case study has basic information that should be used systematically for true results.

Chapter Five discussed basic results and give the comments on this case study; Then, general conclusion and recommendations are outlined for future researches.

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Chapter Two

Literature Review

2.1 Cost Control

2.2 Infrastructure Projects

2.3 Construction Modelling

2.4 Geographic Information System (GIS)

2.5 Previous Studies

المنارة للاستشارات
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2.1 Cost Control

2.1.1 Definition of Cost Control

Cost control process has several definitions according to point of view for many researchers. Cost control process can be defined as:

- "The process of influencing the factors that creates variances; and controlling changes to the project budget" (Glossary, 2005).
- "The systematic recording, classifying and reporting production quantities, utilization of construction resources, analysing performance and managing information for deciding on any corrective actions to ensure that planned project goals are realized" (Abubakar, 1992).
- "Comparing and evaluating the actual cost with the budget value of each individual member, based on the relative regulations of the responsibility system for each individual member"(Yang, 2012).
- "A serious effort - along the project to manage tasks according to realistic plans to complete the project successfully" (Moura *et al.*, 2007).

The most general idea of these definitions is to control the cost of each project element to ensure completion of project with approved budget.

2.1.2 Importance of Cost Control

The importance of cost control is widely recognized by construction professionals in practice. It is related to the fact of the conflict between making enough profit and competitive nature of construction industry. It is a critical balance between needs and abilities. Control process consists of actions taken in response to information, then, it has necessary to get true information to do effective response. (Olawale & Sun, 2010), (Hinze, 2008).

2.1.3 Cost Control Elements

Cost control has some elements that they have to be performed to achieve the needed results. At the beginning, it has to categorise cost control processes into three main phases as (Abubakar, 1992), (Glossary, 2005):

- Cost estimating phase: it is the first phase that defines the basic cost items. It determines materials quantities, labour hours, and subcontracting required. Direct costs are the costs directly attributed to a work-scope, such as labour, material, equipment, and subcontracts; Indirect costs are the costs of operations, overhead and any supporting elements. When the analyzed resource requirements are priced, the result is the estimated project cost.

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- Planning and scheduling phase: it is the second phase that describes how the various work activities will be carried out within the agreed contract period and cost; This phase gives the time dimension and establishes the Work Breakdown Structure (WBS) that is important to categorize the cost.

- Cost evaluating: it is very important phase that can examine the cost control system, in this phase, the performance factors are used to determine which tasks that go on as planned, it deal with several indicators:

  - Actual Cost (AC): it is the total costs actually incurred and recorded in accomplishing work performed during a given time period for a schedule activity or work breakdown structure component. Actual cost can sometimes be direct labour hours alone, direct costs alone, or all costs, including indirect costs.

  - Earned Value (EV): The value of completed work expressed in terms of the approved budget assigned to that work for a schedule activity or work breakdown structure component.

  - Cost Variance (CV): A measurement of cost performance on a project. It is the algebraic difference between the earned value (EV) and actual cost (AC). {CV=EV–AC}, A positive value indicates a favourable condition and a negative value indicates an unfavourable condition.

  - Cost Performance Index (CPI): A measurement of cost efficiency on a project. It is the ratio of earned value (EV) to actual cost (AC). {CPI=EV/AC}, A value equal or greater than one indicates a favourable condition, a value less than one indicates an unfavourable condition.

  - Estimate To Complete (ETC): The expected additional cost needed to complete all the remaining work for a schedule activity, work breakdown structure component, or the project.

  - Estimate At Completion (EAC): The expected total cost of a schedule activity, a work breakdown structure component, or project when the defined scope of work will be completed. EAC is equal to the actual cost (AC) plus the estimate to complete (ETC) for all of the remaining work. {EAC=AC+ETC}, (EAC) may be calculated based on performance to date or estimated by the project team based on other factors, in which case it is often referred to as the latest revised estimate

  - S-Curve: Graphic display of cumulative costs, labour hours, percentage of work, or other quantities, plotted against time. The name derives from the S-like shape of the curve (flatter at the beginning and end, steeper in the middle) produced on a project that starts slowly, accelerates, and then

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trails off. Also a term for the cumulative likelihood distribution that is a result of a simulation, a tool of quantitative risk analysis

- Forecasts: Estimates or predictions of conditions and events in the project's future based on information and knowledge available at the time of the forecast. Forecasts are updated and reissued based on work performance information provided as the project is executed. The information is based on the project's past performance and expected future performance, and includes information that could impact the project in the future, such as estimate at completion and estimate to completion.

2.2 Infrastructure Projects

Infrastructure is a very wide world. It is basic physical and organizational structures needed for the operation of a society, or the services and facilities necessary for an economy to function; In civil construction. It can be communications and transport (roads, railways, harbours, airports, telephones, etc), housing, sewerage, power systems etc. These facilities are usually provided by public authorities and may be regarded as a prerequisite for economic growth in an economy. (Pearce, 1992).

Around the world, infrastructure sector is one of development keys that support any nation, forecasts focus on two key issues: the construction cost and time; and how the facility will serve the whole society, these keys have great impacts on the environmental, social and economic benefits of the project (Siemiatycki, 2010).

The volume of infrastructure investment has accelerated strongly in developing and transition economies, For example, transportation sector in OECD Countries, these countries Spend 1% of GDP on Road and Rail Infrastructure on Average (International transport forum, 2012). From 1992 to 1998, Australian government have invested $30 billion on capital works state-wide and of that approximately $21 billion was for infrastructure projects (MUIM, 1998 cited in Al-Agha, 2005).

Inaccurate forecasts of facility cost make very hard problems for budgeting; It is caused by a variety of factors, some of which are genuine errors, others which result from the strategic actions. Forecasting an uncertain future is inherently difficult, and there are serious technical challenges related to poor data quality, incomplete methods and models, limited time allocated to analysis, and changes in the specifications and scope of the project under evaluation. A study by Bent Flyvbjerg and his colleagues in 2003 of more than 200 transport mega projects in 20 countries on five continents found that development costs were on average 28% higher than forecasted (Flyvbjerg *et al.*, 2002 cited in Siemiatycki, 2010).

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The final goal of infrastructure construction cost control is reducing cost as much as possible based on quality guarantee in order to achieve maximum benefits. Therefore, it is very important to control the project cost during the project implement. The project construction cost control mainly includes scientific plan, control and verification to labour, materials, and cost consumed during the project implement; It needs active involvement and close cooperation of everyone involved in the project. (Yang, 2012), (European Union, 2010).

Urban physical infrastructure can be classified into main categories:

- Transport systems: railways, motorways, parking areas, bridges, tunnels.
- Water supply: supply pipes, reservoirs, pump stations, storing tanks, fire-fighting hydrants.
- Sewerage drainage: collection pipes, pump stations, treatment planets.
- Storm water drainage: collection pipes, pump stations, infiltration basins.
- Power supply: supply lines, generating stations, transformers.
- Communication network: service providers, transmission lines.

Each of these categories has its special components due to engineering design. Specifications and quantities have to be incorporated in contract documents. Detailed drawings show the location of each element that has to be established. Contract documents classify these elements into items that have pre-specified quantities and prices. It is known Bill Of Quantities (BOQ).

These types of infrastructures are lay on wide area of earth, it is difficult to manage them by manual methods. The hole image with huge data cannot be illustrated in one layer, so, GIS can be used very well as multi layer system to manage the huge data.

2.3 Construction Modelling

A scientific model is a simplified abstract view of a complex reality. A scientific model represents empirical objects, phenomena, and physical processes in a logical way. Attempts to formalize the principles of the empirical sciences use an interpretation to model reality. The aim of these attempts is to construct a formal system for which reality is the only interpretation.

Modelling and simulation (M&S) is getting information about how something will behave without actually testing it in real life. It depends on large raw data to manage them in a scientific way. The benefit of (M&S) can be felt in large-scale projects, which is very difficult to be managed or controlled by traditional ways. It is so difficult to predict any indirect effects of any planed action or variation. Computerized modelling of reality can offer these capabilities, it can provide the ability to perform several scenarios, tracking project progress, and control each item and element by providing fast-accurate information in order to help managers.

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2.4 Geographic Information System (GIS)

2.4.1 From Manual to Computer

Traditionally, paper forms, triangle scale, and some simple tools were widely used for quantity survey; time schedules, histograms, and the famous S-curve were produced by hand. Later, CAD software and other computerized methods replaced these old methods. Computers presented new powerful abilities to perform speed-accurate processes that save time. Several software packages were used to perform specific functions: quantity survey, forecasting, writing reports, etc… (Ostwald, 2001).

The greatest challenge facing construction managers today is to find the most efficient way of managing construction site, and to develop construction plans to meet clients' cost and time requirements. An improvement of managing construction site can be achieved by implementing management forms, which emphasize co-operation, delegation, continuous learning and the use of information technology. Construction managers rely on ready access to a large amount of project information. The entry, processing, and flow of information are important in avoiding problems, delays, and claims on construction projects. Thus, information technology and database engines get its importance according to its ability to make the work more efficient and easy. (Mohamed & Anumba, 2004), (Shahid & Froese, 1998), (McKinney & Fischer, 1998).

With more complexity of engineering constructions, engineers used to depend more and more on computers to insure accurate performance within planed times. New software packages were developed to make work easier, more functions were added, and user interfaces became more easy to use. However, the need for more specialized software got more importance.

2.4.2 GIS Definition and Capabilities

Geographic Information System (GIS) is a comprehensive application system, which integrates geography, geometry, CAD technology, remote sensing, GPS technology, internet, multimedia, etc… It can offer virtual reality technology. Utilize computer graphics and database technology to provide efficient ways to store, analyze, and update data. GIS deals with multilayered database. Moreover, it can be used to process information and present it to the end users in human recognizable formats such as images, graphs, charts etc… Representing all kinds of information related to location visually enable GIS to be used in a lot of engineering applications (Wan-Mohamad & Abdul-Ghani, 2011), (Yao et al, 2011), (Balbahaith, 2010).

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GIS has so many benefits, such as:

- Automating Information and transferring them from paper to digital format (paperless system).
- Linking location and attributes of features within the framework of one system.
- Providing the ability to manipulate and analyze Information accurately that is very hard manually.
- Automation of map making, production and updating.
- Providing a unified database that can be accessed by more than one department or agency.

2.4.3 Civil Engineering and GIS

A system that could provide means to efficiently stored, analyzed, updated data, and then could produce other forms of information such as maps and tables is something that could expedite decision-making. These kinds of systems will be useful to engineers and planners in land development industry. GIS is known to be able to provide these facilities as it can store information in a multilayered database. Moreover, it can be used to process information in spatial data. Thus, GIS is used in many engineering applications such as in geotechnical, environment, human resources, construction, transportation, etc… (Wan-Mohamad & Abul-Ghani, 2011), (Maji & Jha, 2011)

GIS can produce visual view to any problem, visualization aid in many stages of problem solving with GIS. Using additional and alternative elements such as timelines may also be effective in supporting problem solving. Utilizing these advantages in construction sector can provide more power to identify conflicts. GIS offer so many tools to deal with any problem by intelligent datasets, advanced editing, ability for work with vector and raster data, derivative information produced by analytical and statistical methods.(Howarth & Sinton, 2011), (Esri, 2006).

In the 21st Century, technological developments in the areas of remote sensing, geographic information systems and wireless communications have made huge strides as a result of great changes in mobile networks – mobile phones, vehicle navigation, smart cards and personal tracking systems. (Lee, 1999 cited in Lee *et al.*, 2008).

Wireless and advanced technologies such as Global Position System (GPS) provide opportunities for a person to communicate with any product or service elements of the existing urban infrastructure, notably transport, water supply, public parks and route directions. These physical infrastructure items can be monitored, controlled and protected very easily (Lee et al., 2008).

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2.5 Previous Studies

In practice, 3D and 4D technologies have been applied on a variety of construction projects. Prior research efforts have compiled detailed case studies that assess the benefits and limitations of these tools and their impact on project performance, (Staub-French and Fisher, 2001), (Kam *et al.*, 2003).

Researchers have also critiqued the functionality of 3D and 4D technologies to meet the needs of industry (McKinney and Fischer 1998), (Songer *et al.*, 1998), (Koo and Fischer, 2000), (Heesom and Mahdjuobi, 2004). Some research efforts have also investigated the application of 3D and 4D modelling tools for specific purposes, such as constructability analysis (Ganah et al. 2005) and resource management (Akinci et al. 2003). Other research studies have documented the benefits and challenges of applying 3D / 4D tools specifically to the coordination of Mechanical, Electrical, Plumbing, and Fire Protection systems on complex projects (Khanzode *et al.*, 2005, Staub-French and Fischer, 2001). Finally, researchers have also investigated techniques to enhance the interaction capabilities of 3D and 4D models using immersive technologies (Messner et al., 2006) and virtual reality (Whyte et al., 2000). These studies clearly demonstrate that 3D/4D technologies have been well established and can be applied to resolve complex design and construction challenges. Although much has been written on the application of 3D and 4D technologies, few guidelines exist that outline what is required to apply these tools in real time on actual construction projects. (Staub-French and Khanzode, 2007).

However, some managerial groups in the world construct their own applications to manage their projects, and then they offer their applications to others in order to spread these experiences as leaders in E-managing. Most of these applications are based on using database capabilities to document and queering information about any item in project. These applications has its high prices according to its importance and capabilities, brochures of these applications show that only database technology is the most important key, then the graphs as curves and histograms can be produced, few little drawings and maps are shown.

About dividing the project into levels, several researches deal with project levels of managements, each level concerns on specified objective to achieve, for example, Al-Tabbaa' divide the project into several levels in order to construct a model that can estimate the required time of project in planning phase, division of project into levels can give simple tool to control projects tasks with their interactive time and resources(Al-Tabbaa', 2005). Similar method can be adopted to cost control, dividing project into levels can simplify cost control processes and give the ability to get the objected information about several levels according to needed level of management, Also, this is compliant to WBS concept that divide whole project into components for better management processes.

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Chapter Three

The developed System

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3.1 Introduction

In this chapter, the main concepts of the developed system will be established and discussed according to research methodology that is mentioned in Chapter One. The main goal of this system is to improve the cost control process for infrastructure projects. It is known that infrastructure sector has its importance around the world.

3.2 Background

The main object of cost control process is to ensure that the project should be accomplished according to project budget. Budget allocates expenditures on project items according to project plans. Therefore, cost control process should deal with these items each alone in view of whole project. It is not sufficient to control the total price only, improvement by item tracking have to be performed.

Bell Of Quantities (BOQ) and Drawings are basic parts of contractual documents; They describe the tangible components that should be established on site. In practice, they are the most used documents at implementation phase; combination with each other is very basic for cost calculations generally and cost control specially.

BOQ deals with general details of project components that are divided into contractual items. Each contractual item has its attributes, as: serial number, general description, measurement unit, unit price, contractual quantity and contractual price. It is the basic information that the contract depends on to deal with financial side. General specifications are involved in BOQ to decide what materials and methods of work should be used at general management level.

Drawings illustrate more details of project components. It shows more detailed specifications of each element on site, as site allocation, geometry measurements (length, area, etc…), cross sections, and existing constructions in site or around. Detailed specifications are involved in drawings to decide what materials and methods of work should be used at task management level.

In past, paper documents were used to implement project tasks. Deteriorations and loss were common problems because of much hand use. Farther more, human mistakes were common and causes work interruptions. Now, several software packages are used to solve these problems, handling and save information become easier, accurate information can be produced and work become more efficient.

In some cases, mismatch between BOQ and drawings can occur. Human mistakes, repeated modifications of scope and specifications, then poor reviewing of contractual documents are common causes. In these cases, contractual problems raised at implementation phase.

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3.3 Methodology

As mentioned in Chapter One, the main goal of this system is to improve the cost control process for infrastructure projects. Then, objectives can be considered as:

1. Investigate the applying of cost control in Gaza Strip.
2. Identify the basic indicators of cost control process.
3. Build conceptual model and establish computerized system.

Figure 3.1 illustrates the main steps of applied methodology:

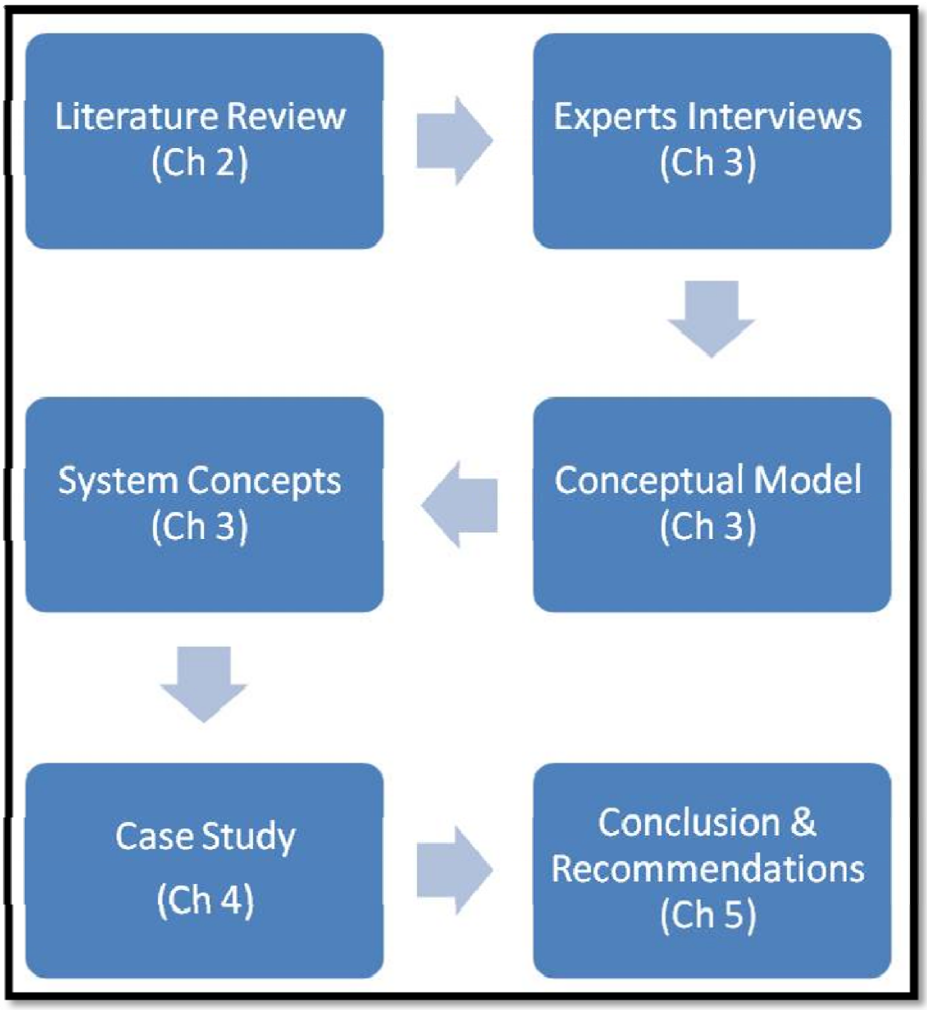

Figure 3-1 Thesis framework

About the first objective, it can be achieved by comprehensive literature review and personal interviews with experts. Literature review was performed to gather basic information about cost control topic. According to previous researchers, cost control process is a chain of processes along project lifetime, starting at estimations phase through planning phase and construction evaluating phase, then operating phase to end of project. This research focuses on construction evaluating phase as one of the main phases that depend on construction engineering management.

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Interviews can help to investigate opinions about the applying of cost control and common difficulties; Interviews were made with engineers whose have at least 5 years of experience. Some of them work as consultants while others work as contractors. Main questions of these interviews are about:

1) What kind of infrastructure projects that were performed in Gaza Strip?
2) What procurement type is the most used in Gaza Strip?
3) What are the common concepts of cost control according to local knowledge?
4) What are the aims of cost control according to contractor and consultant?
5) Are cost control concepts applied really in Gaza Strip? What are difficulties?
6) What kind of information can be helpful for both of contractor and consultant?
7) If there is a computerized system that applies cost control processes, can it be used or not, how can it be used?

The main common result was about the poor application of cost control processes in Gaza Strip, according to their opinions, the main answers are:

1) Main infrastructure projects in Gaza Strip are motorways, water networks, sewage networks, storm networks, electricity networks and telecommunications networks; Few projects of other types as bridges, infiltration basins, and waste water and solids treatment plants; But, no gas networks, no railways, no advance communications networks, no natural resources rehabilitation except two projects in Wadi Gaza.
2) Most of projects are unit price projects; it is the most dynamic type that can meet unexpected conditions especially in infrastructure projects.
3) There is no intension about cost control issues; there is a very poor knowledge about it.
4) According to point view of consultants, the most important thing is keeping the whole project within the budget. Regardless the cost variances of each item alone; so, the most used approach is only the forecasting for total summation of project price; on other side, according to point view of contractors, the most important thing is obtaining maximum benefit of whole project. Regardless the benefits of each item alone; so, the most used approach is manipulation with materials specifications and using marginal sub-contractors.

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5) Gaza Strip is a closed area that suffers from security and political situation. There is no large-scale projects, no large budgets; so, no intention about managing sufficient money.

6) The only issue that can be dealt is keeping quantity survey within 25% of baseline BOQ according to contract conditions; cost control indicators can be helpful to both of contractor and consultant if they are concerned.

7) Computerized system that can perform cost control processes is good idea; but, it is sufficient only in large-scale projects, there is necessary to training on GIS software, training on good skills of detailed data collection in site, neither of contractors nor of consultants used to work with this advanced techniques.

Although this dark image, most of these experts consider that it is necessary to develop cost control applying in Gaza Strip to be similar to other developing areas; Then, computerized system can make this develop very easy; More awareness about cost control importance can make positive change to best trends.

About the second objective, both of literature review and interviews give the basic indicators of cost control process. Cost Variance (CV), Cost Performance Index (CPI), Estimation To Completion (ETC), Estimation At Completion (EAC) and progress ratio are selected as interested values that are needed to perform cost control. Also, cost forecasting process has its importance for managing future scenarios that can be predicted. Experts mention to big importance of recording for actual costs (AC) systematically. These values are the basic values that have to be considered for performing success cost control.

About the third objective, conceptual model has been built according to concepts that be obtained from first and second objectives; what are the system inputs, processes, and outputs? what are control levels and its objectives?, and how to model physical project components in computerized system?, these questions will be answered comprehensively in this chapter sections. Computerized system has been established with full requirements, ArcGIS v.10 package is selected as GIS software, data input methods are cleared, needed software features like feature classes and tables are established, concepts of cost control can be modelled by easy methods.

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3.4 Limitations

After gathering the required knowledge about cost control application in Gaza Strip, the research is limited the developed system by these limitations:

1) The developed system can be applied in Gaza Strip environment; According to most of engineers, the difference between Gaza Strip and the other areas is very large. For example, in Gaza Strip there are no standard organizing for contractual Items, and no cost coding except item number.

2) The developed system deals with cost control in cost evaluation phase only; Estimation phase and planning phase should not be covered in this research.

3) The developed system is suitable for unit price projects; it is difficult to manage other types of project procurement.

3.5 Conceptual Model

3.5.1 Data Flow

The conceptual model involves three control levels that data flow through. Each level has its input data, processed data, and output data. Output data that produced from each level will be input data in the next level. Figure 3.2 illustrates generally data flow through control levels due to conceptual model.

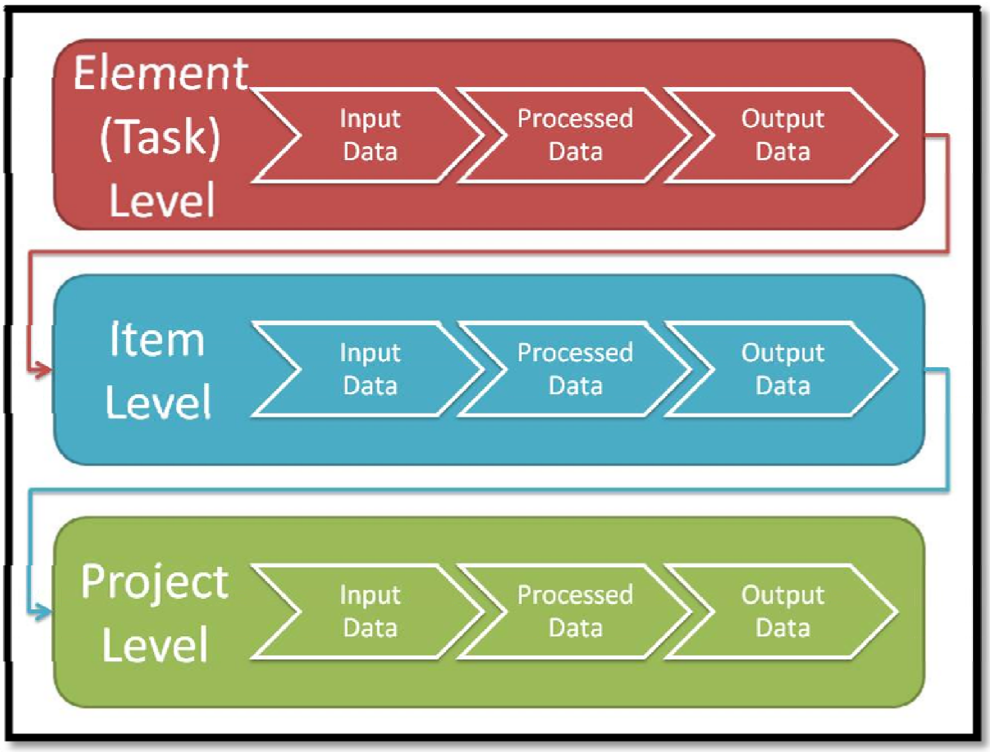

Figure 3-2 Data flow through control levels

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3.5.2 Control Levels

The conceptual model depends on three control levels:

- Element (task) Level.
- Item Level.
- Project Level.

3.5.2.1 Element (Task) Level

Element (task) level can be considered as data collection level. This level organizes the basic input data in order to manage it later. The control at element level requires very good records about each detail. The conceptual model aims to perform accurate quantity surveying of each elements according to drawings, A very detailed control requires more effort, but, it can give more accurate information in order to identify any problem at early time.

Although cost control processes should start at item level; But, in optional cases, these processes can be perform to selected item in order to study this item elements to identify any problems; Then, accurate records for actual costs have to be performed for each element and these actual costs should be allocated on each element according to work methods in order to track each element.

3.5.2.2 Item Level

Item level can be considered as data management level. Item level concerns on getting the required indicators about cost control of each contractual item of project; Managing of each contractual item can identify the success or problems for each item of project, it can control allocation of costs and benefits rather than final summation value, then, correction actions can be decided based on accurate information. This level contains three main components:

- Actual cost Records
- Cost performance indicators
- Cost forecasting

3.5.2.2.1 Actual Cost Records

Actual cost records for items have to be gathered accurately; Accurate records for actual costs have to be performed for each contractual item: materials, equipments, man hours, and other expenditures records (insurance, transportations, communications, etc…), these actual costs should be allocated on each item according to work methods in order to track items.

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3.5.2.2.2 Cost Performance Indicators

Cost performance indicators can give numerical scales for implementation progress; Also, it can give prediction for later tasks. Cost Variance (CV), Cost Performance Index (CPI), Estimation To Completion (ETC), Estimation At Completion (EAC) and progress ratio are considered as performance indicators.

Cost Variance (CV) and Cost Performance Index (CPI) can be useful to identify which items is going on successfully and which experiences problems. It can identify any loss at early time, correction actions have to be applied in order to ensure that later tasks can go on successfully.

Estimation To Complete (ETC) and Estimation At Completion (EAC) can be useful to control items within the project plan, how much money spent and how much money estimated to spend until project finish, what can do to complete project within assigned budget. In addition, it can identify any potential overrun at early time.

3.5.2.2.3 Cost Forecasting

Cost forecasting can give numerical answer for how can be re-allocated quantities and prices among project elements; also, it can give prediction for later tasks.

Forecasting processes depend on real predictions that are based on project progress and plan development, changes of quantity are common event specially in infrastructure projects due to many unexpected conditions in large site, therefore, re-allocation of quantities and prices can give the dynamically to perform tasks according to well controlled prices.

3.5.2.3 Project Level

Project level can be considered as an overview on whole project, management at project level concern on inferring the brief required information that is needed by all parties in meeting or progress reports; this level contains two main components:

- Project claims
- Project cost evaluation

3.5.2.3.1 Project Claims

Preparing of claims has to be performed by good data collection from site, and accurate quantity survey. Contractual conditions assigned surety bonds

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that can be considered as reduction factor for each approved earn value, this surety bonds end after maintenance period according to contract.

3.5.2.3.2 Project Cost Evaluation

Project Cost Evaluation is the brief summary of cost control of whole project; all cost control processes are summarized in order to review whole project status.

3.6 Selected Software

The selected software is ArcGIS v10 by ESRI (Environmental Systems Research Institute); it is a geographic information system (GIS) for working with maps and geographic information; it is used for: creating and using maps, editing, compiling and analyzing data, and managing information in a database.

ArcGIS can handle with coverages, shape files, grids, images, Vector Product Format (VPF), Triangulated Irregular Network (TIN), Computer Aided Design (CAD), and many formats of tables and databases.

ArcGIS for Desktop consists of several integrated applications, including ArcMap, ArcCatalog, and ArcToolbox. ArcCatalog is the data management application, used to browse datasets, database, or other sources; also provides the ability to view and manage metadata for spatial datasets. ArcMap is the application used to view, edit and query geospatial data, and create maps; ArcMap interface has two main sections, table of contents and the data frame which display the map; Items in the table of contents correspond with layers on the map. ArcToolbox contains geoprocessing, data conversion, and analysis tools; it is also possible to use batch processing with ArcToolbox, for frequently repeated tasks. (Esri, 2004).

There are a number of software extensions that can be added to ArcGIS that provide added functionality, including 3D Analyst, Spatial Analyst, Network Analyst, Survey Analyst, Tracking Analyst, Geostatistical Analyst, and Maplex extension; Numerous extensions have also been developed by third-parties. (Esri, 2004).

This software is selected for reasons:

- It is the most common used software in Gaza Strip.
- The ability to compile and use third-party extensions within ArcGIS environment, this can give the ability to develop the system later.

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3.7 System Concepts

3.7.1 Input Data

As mentioned in this chapter introduction, BOQ and drawings are the basic documents that are used in cost control process. In Gaza Strip, BOQ calculations are processed often with Microsoft Excel, while drawings are often produced and modified with Autodesk AutoCAD.

ArcGIS by ESRI can use GIS capabilities to manage both BOQ and drawings as integrated documents. Generally, input data can be divided into two items: spatial data and tables.

About drawings, it can be modelled as spatial data; it can be entered directly in ArcGIS, or imported from CAD file. It is very essential to use a specified projected coordinate system in order to:

- Display the project in its real placement and scale.
- Ability to display any overlay with other near projects or surrounding environment.
- Ability to perform geoprocessing calculations that is very important in quantity surveying of scaled items.
- Ability to use GPS to perform works.

About BOQ, it can be entered as a table; it can be entered directly in ArcGIS, or imported from Database, Excel or delimited TXT file. Additional tables can be established and joined at different management levels in order to perform cost control processes.

3.7.2 Quantity Surveying

The developed system uses GIS capabilities to calculate geometry properties, the main advantage of this system is the direct linkage between feature and its attributes that can store feature properties; Point as zero dimension geometry can be useful to model unity unit features, line as one dimension geometry has length property that can be useful to model length unit features, polygon as two dimensions geometry has area and perimeter properties that can be useful to model area unit features. It is difficult to model volume and weight geometries directly in GIS; In order to defeat this shortage, additional attributes that present quantity per geometry data must be established to calculate volume and weight quantities.

Instead of using 2-dimentional features that can be modelled in single plane (point, line, polygon), it is more effective to use 3-dimentional features that can be

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modelled in space (pointZ, lineZ, polygonZ); the main reasons to use these 3-D features are:

- More accurate geometry calculations can be performed.
- Ability to produce 3-D views that can model and show physical components more reality.

3.7.3 Control Levels

According to conceptual model, the developed system depends on three control levels: Element (task) Level, Item Level, Project Level. Figure 3.3 illustrates these levels with their software components.

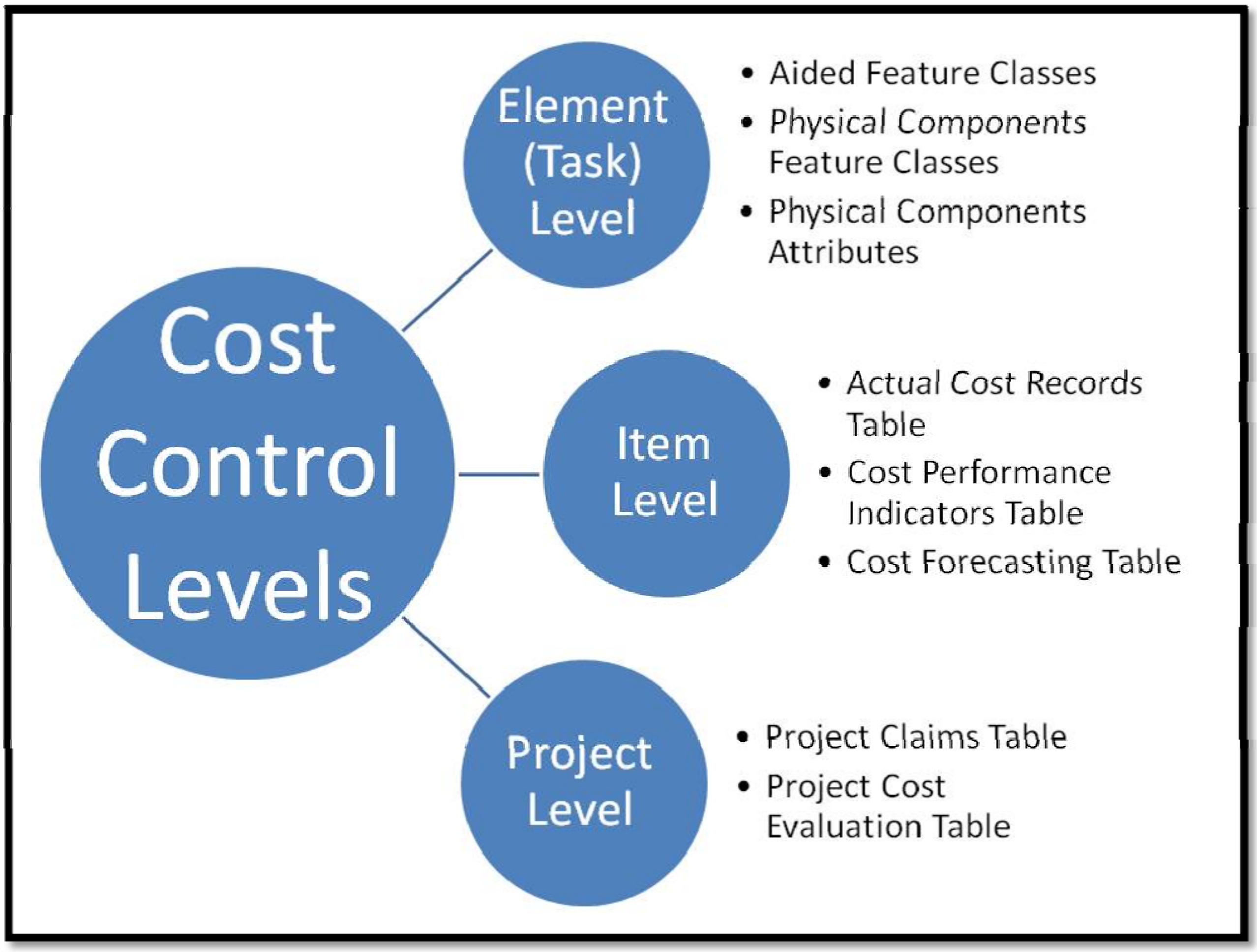

Figure 3-3 Cost control levels

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3.8 The Developed System Components

The developed system depends on modelling physical components by feature classes that have their attributes; then, several tables can inherit data from these attributes to perform cost control processes; finally, the required information can be shown by visual means that offered by ArcGIS capabilities, the following tables could illustrate these main components.

Table 3.1 illustrates main components of element (task) level of cost control. In this level feature classes have to be established to model the physical elements of project, Each feature class has its attributes table that is used for storing needed information, according to model, these information have to pass through three steps: input, processing, and output. Input fields can be fed by manual methods or computerized methods, some of these fields get its information by geometry tools that depend on GIS capabilities especially for quantity surveying data. Processing fields are calculated by expressions depending on information in input fields. Outputs can be visual outputs or embedded outputs. Visual outputs can be shown on data frame window that present project map. Legends, labels, identify orders, query orders and layouts can be performed very easy by ArcGIS capabilities. Embedded outputs are summarizing for some fields that can get output values of all records in feature class to produce input values for next level. In others words, output values of element (task) level are input values of item level.

Table 3.2 illustrates main components of item level of cost control. This level is a cost control level. In this level there are three tables: actual cost records, cost performance indicators, and cost forecasting. Actual cost records can be fed entirely by manual method, all actual costs should be entered and allocated on contractual items. Summarizing of these values according to its items ids can give actual costs inputs for the other two tables. Cost performance indicators concerns on calculating CV, CPI, ETC, EAC, and progress ratios for each item. This table gives needed details for cost control item by item in order to perform successful control. Cost forecasting concerns on forecasting of costs and can give the ability for re-allocating budget on several items, it can give the ability to study several scenarios. according to model, these information have to pass through three steps: input, processing, and output. Input fields can be fed by manual methods or computerized methods (summarized data). Processing fields are calculated by expressions depending on information in input fields. Outputs can be visual outputs or embedded outputs. Visual outputs can be shown basically by so many charts that can give the ability to see and compare data, it can be performed very easy by ArcGIS capabilities. Embedded outputs are summarizing for some fields that can get output values of all records in table to produce input values for next level. In others words, output values of item level are input values of project level.

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Table 3.3 illustrates main components of project level of cost control. In this level there are two tables: project claims, project cost evaluation. Project claims can be fed by claims information. Summarizing of these values and actual cost records values according to their dates can give comparative S-curve that can be produced by ArcGIS capabilities as visual output. On other side, project cost evaluation table can give final conclusion about overall project values of cost control. Finally, it can be performed a comprehensive report that can contain lots of cost information tabulated or in visual form by charts by using report formats those are pre-designed as needed.

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Table 3-1 Element (task) level components

	Input Data: External (optional)	Input Data: Internal (ArcGIS)	Processes	Output Data
	GIS, CAD	Aided Features: • Survey Stations • Existing Constructions • DEMs		
Element (Task) Level	GIS, CAD	**Physical Components Feature classes:** • Each (unity unit) item (PointZ) • Each (length unit) item (LineZ) • Each (area unit) Item (PolygonZ) • Each (volume unit) item (LineZ/PolygonZ feature class with quantity per length/area geometry) • Each (weight unit) item (LineZ/PolygonZ feature class with quantity per length/area geometry)		Legends: • Progress legend • Claim legend Optional Legends: • CV legend • CPI legend Labels: • ELMNT_ID • ITEM_ID • ElMNT_PLN_QUANTITY • ELMNT_PLN_PRICE(currency) • ELMNT_EV • ELMNT_APRV_EV Identify Orders Query Orders Layouts
Element (Task) Level	Database, CAD, Excel, delimited TXT	Main attributes: • ELMNT_ID • ITEM_ID • ITEM_DESCRIPTION • ITEM_UNIT • UNIT_PRICE(currency) • GEOMETRY_QUANTITY Tracking attributes: • ELMNT_STATUS • CMPLT_RATIO • CLAIM_ID • CLAIM_DATE Optional attributes: • ELMNT_AC(currency)(optinal)	Processes attributes: • ELMNT_GEOMETRY • ELMNT_PLN_QUANTITY • ELMNT_PLN_PRICE(currency) • ELMNT_EV(currency) • ELMNT_APRV_EV(currency) Optional processes attributes: • ELMNT_CV(currency)(optional) • ELMNT_CPI(optional)	Summarizing attributes: • ELMNT_PLN_QUANTITY '1' • ELMNT_PLN_PRICE(currency) '2' • ELMNT_EV(currency) '3' • ELMNT_APRV_EV(currency) '4'

Notes:

Summarizing attributes are outputs of Element (Task) Level that should be inputs to Item Level:

- ELMNT_PLN_QUANTITY '1': summations of this field according to ITEM_ID field
- ELMNT_PLN_PRICE(currency) '2': summations of this field according to ITEM_ID field
- ELMNT_EV(currency) '3': summations of this field according to ITEM_ID field
- ELMNT_APRV_EV(currency) '4': summations of this field according to ITEM_ID field

Abbreviations:
DEM: Digital Elevation Model, ELMNT: Element, CMPLT: Completion, PLN: Planned (according to plan or drawings), APRV: Approved, AC: Actual Cost, EV: Earned Value, CV: Cost Variance, CPI: Cost Performance Index

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Table 3-2 Item level components

Level	Source	Input Data	Processes Data	Summarizing Data
ITEM Level		**Actual Cost Records table**		
	Database, Excel, delimited TXT	Input Data: • AC_DATE • AC_DESCRIPTION • AC_VALUE(currency) • AC_ITEM_ID • AC_CLASS		Summarizing Data: • AC_VALUE(currency) '5' Charts for Data: • AC_VALUE(currency)
		Cost Performance Indicators table		
	Database, Excel, delimited TXT	Input & Inherited Data: • ITEM_ID • ITEM_DESCRIPTION • ITEM_UNIT • UNIT_PRICE(currency) • ITEM_CNTRCT_QUANTITY • ITEM_CNTRCT_PRICE(currency) • ITEM_PLN_QUANTITY '1' • ITEM_PLN_PRICE(currency) '2' • ITEM_EV(currency) '3' • ITEM_APRV_EV(currency)'4' • ITEM_AC(currency) '5'	Processes Data: • ITEM_CV(currency) • ITEM_CPI • ITEM_ETC(currency) • ITEM_EAC(currency) • ITEM_PLN_PROGRESS • ITEM_CNTRCT_PROGRESS	Summarizing Data: • ITEM_CNTRCT_PRICE(currency) '6' • ITEM_PLN_PRICE(currency) '7' • ITEM_EV(currency) '8' • ITEM_APRV_EV(currency) '9' • ITEM_AC(currency) '10' Charts for Data: • UNIT_PRICE(currency) • ITEM_CNTRCT_QUANTITY • ITEM_CNTRCT_PRICE(currency) • ITEM_PLN_QUANTITY • ITEM_PLN_PRICE(currency) • ITEM_EV(currency) • ITEM_APRV_EV(currency) • ITEM_AC(currency) • ITEM_CV(currency) • ITEM_CPI • ITEM_ETC(currency) • ITEM_EAC(currency) • ITEM_PLN_PROGRESS • ITEM_CNTRCT_PROGRESS
		Cost Forecasting table		
	Database, Excel, delimited TXT	Input & Inherited Data: • ITEM_ID • ITEM_DESCRIPTION • ITEM_UNIT • UNIT_PRICE(currency) • ITEM_CNTRCT_QUANTITY • ITEM_CNTRCT_PRICE(currency) • ITEM_PLN_QUANTITY '1' • ITEM_PLN_PRICE(currency) '2' Optional Data: • ITEM_SPS_QUANTITY	Processes Data: • ITEM_PLN_VARIANCE(currency) Optional Data: • ITEM_SPS_PRICE(currency) • ITEM_SPS_VARIANCE(currency)	Summarizing Data: • ITEM_CNTRCT_PRICE(currency) '6' • ITEM_PLN_PRICE(currency) '7' • ITEM_SPS_PRICE(currency) '11' Charts for Data: • UNIT_PRICE(currency) • ITEM_CNTRCT_QUANTITY • ITEM_CNTRCT_PRICE(currency) • ITEM_PLN_QUANTITY • ITEM_PLN_PRICE(currency) • ITEM_PLN_VARIANCE(currency) Optional Charts for Data: • ITEM_SPS_QUANTITY • ITEM_SPS_PRICE(currency) • ITEM_SPS_VARIANCE(currency)

Notes:

Summarizing data are outputs of Item Level that should be inputs to Project Level:

- AC_VALUE(currency) '5': summations of this field according to AC_ITEM_ID field
- ITEM_CNTRCT_PRICE(currency) '6': summations of this field for all records
- ITEM_PLN_PRICE(currency) '7': summations of this field for all records
- ITEM_EV(currency) '8': summations of this field for all records, and counting values of this field
- ITEM_APRV_EV(currency) '9': summations of this field for all records
- ITEM_AC(currency) '10': summations of this field for all records
- ITEM_SPS_PRICE(currency) '11': summations of this field for all records

Abbreviations:

CNTRCT: Contractual, PLN: Planned (according to plan or drawings), SPS: supposed, APRV: Approved, AC: Actual Cost, EV: Earned Value, CV: Cost Variance, CPI: Cost Performance Index, ETC: Estimated To Complete, EAC: Estimated At Completion

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Table 3-3 Project level components

Project Level		**Project Claims table**		
		Input & Inherited Data: • CLAIM_ID • CLAIM_DATE • CLAIM_VALUE(currency) • CLAIM_CMLTV_VALUE(currency) • CLAIM_CMLTV_AC(currency)	Processes Data: • BENEFIT/LOSS(currency)	Summarizing Data: • CLAIM_ID '12' • CLAIM_VALUE(currency) '13' Charts for Data: • CLAIM_VALUE(currency) • BENEFIT/LOSS(currency) S-curve for Data: • CLAIM_CMLTV_VALUE(currency) • CLAIM_CMLTV_AC(currency)
		Project Cost Evaluation table		
		Input & Inherited Data: • PRJCT_ID • PRJCT_NAME • PRJCT_CNTRCT_PRICE(currency) '6' • PRJCT_PLN_PRICE(currency) '7' • PRJCT_EV(currency) '8' • PRJCT_APRV_EV(currency) '9' • PRJCT_AC(currency) '10' • PRJCT_ITEMS_ON '8' • PRJCT_ITEMS_YET '8' • CLAIMS_APRV '12' • CLAIMS_TOTAL(currency) '13' Optional Data: • PRJCT_SPS_PRICE(currency) '11	Processes Data: • PRJCT_CV(currency) • PRJCT_CPI • PRJCT_ETC(currency) • PRJCT_EAC(currency) • PRJCT_PLN_VARIANCE(currency) • PRJCT_PLN_PROGRESS • PRJCT_CNTRCT_PROGRESS Optional Data: • PRJCT_SPS_VARIANCE(currency)	Reports

Notes:

Summarizing data are outputs of Project Level that should be inputs in same Level:
- CLAIM_ID '12': counting values of this field
- CLAIM_VALUE(currency) '13': summations of this field

Abbreviations:
PRJCT: Project, CMLTV: Cumulative, CNTRCT: Contractual, PLN: Planned (according to plan or drawings), SPS: supposed, APRV: Approved, AC: Actual Cost, EV: Earned Value, CV: Cost Variance, CPI: Cost Performance Index, ETC: Estimated To Complete, EAC: Estimated At Completion

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3.8.1 Basic Feature Classes

Infrastructure projects have several main components, the objected components can be considered as main categories. The contractual items that are within these categories (sub-categories) modelled as feature class files, each of these items has its quantity unit that decide how can it be modelled; Then, other basic information are found in attributes table.

The first stage is the feature model of contractual items:

Each main category	Group title
• Each (unity unit) item	PointZ feature class
• Each (length unit) item	LineZ feature class
• Each (area unit) Item	PolygonZ feature class
• Each (volume unit) item	LineZ/PolygonZ feature class with quantity per length/area geometry
• Each (weight unit) item	LineZ/PolygonZ feature class with quantity per length/area geometry

Now, each element of these works can be modelled by GIS feature, and then it can be viewed in date frame of ArcGIS instead of paper or CAD drawings.

The second stage is the basic attributes of each feature:

- ELMNT_ID: element ID as in drawings (text)
- ITEM_ID: contractual Item number. (text)
- ITEM_DESCRIPTION: contractual Item description. (text)
- ITEM_UNIT: contractual quantity unit. (text)
- UNIT_PRICE(currency): contractual unit price due to contractual currency. (float)
- ELMNT_GEOMETRY: element quantity according to its feature class: (float)
    - o PointZ feature: 1.000 (unity unit).
    - o LineZ feature: element length according to contractual unit, it can be calculated from feature geometry, map unit must be converted to contractual unit.
    - o PolygonZ feature: element area according to contractual unit, it can be calculated from feature geometry, map unit must be converted to contractual unit.

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- GEOMETRY_QUANTITY: this field used basically to calculate (volume/weight) unit contractual items, it is the quantity per unit of element geometry (length/area.), generally, this field can be edited according to feature class as: (float)
    - Each (unity unit) contractual item: 1.000
    - Each (length unit) contractual item: 1.000
    - Each (area unit) contractual Item: 1.000
    - Each (volume unit) contractual item: quantity per geometry unit, map unit must be converted to contractual unit.
    - Each (weight unit) contractual item: quantity per geometry unit, map unit must be converted to contractual unit.

- ELMNT_PLN_QUANTITY: planed quantity of each element according to drawings (float)

  ELMNT_GEOMETRY * GEOMETRY_QUANTITY

- ELMNT_PLN_PRICE(currency): price of each element according to drawings (float)

  UNIT_PRICE * ELMNT_PLN_QUANTITY

Each element in the project can be viewed in ArcGIS data frame; Then, it can be performed any query or labelling order to view attributes for any element on map.

3.8.2 Additional Feature Classes

- Survey stations: it can be considered as control points. It is used for locating project elements along project site, controlling elevation levels, and dividing of scaled elements into parts for quantity survey. These stations should be modelled as separate point feature class.

- Digital Elevation Model (DEM): it can represent the topography of site surface, it can be useful for cut/fill calculations.

- Existing constructions: any existing constructions can be modelled as separate feature classes. It is very useful data that can show any obstacles that cannot be seen underground.

3.8.3 Element (Task) Level Attributes

Additional fields should be added to each feature for implementation status:

- ELMNT_STATUS: status of implementation for each element if it is finished or not, there are four cases: (text)

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- Yes: indicate that the element finished according to contractual conditions; Then, its ELMNT_PRICE value can be considered as Earned Value (EV).
- On: indicate that the element is being performed (current task); Its ELMNT_PRICE cannot be considered as (EV); But, in special cases, consultant can approve specified ratio as (EV).
- No: indicate that the element is not performed yet; Its ELMNT_PRICE cannot be considered as (EV) at all.
- Off: indicate that the element is cancelled to perform due to consultant approval; All of its attributes are null value.

- CMPLT_RATIO: completion ration of each element; This value depend on ELMNT_STATUS value: (float)
  - ELMNT_STATUS (Yes): 1.00
  - ELMNT_STATUS (On): a ratio be approved by consultant
  - ELMNT_STATUS (No): 0.00
  - ELMNT_STATUS (Off): null

- ELMNT_EV(currency): earned value of each element according to contractual conditions; The value is calculated as: (float)

  ELMNT_PRICE * CMPLT_RATIO

  In case of full completion, this value equal ELMNT_PLN_PRICE
  "If ELMNT_STATUS (Off), this value is null"

- CLAIM_ID: claim ID of approved elements by consultant according to contractual documents; This value depends on ELMNT_STATUS value: (text)
  - ELMNT_STATUS (Yes): claim ID
  - ELMNT_STATUS (On): claim ID or (---)
  - ELMNT_STATUS (No): (---)
  - ELMNT_STATUS (Off): null

- CLAIM_DATE: the date of claim approval. (date)
  "If ELMNT_STATUS (Off), this value is null"

Reviewing CLAIM_ID field can identify witch elements have been completed and approved. Non approved elements that have no CLAIM_ID values should be considered as incomplete elements due to contractual conditions even they have been completed in site, thus, additional fields have to be added to each feature as:

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- ELMNT_APRV_EV(currency): approved earn value of each element; This field depends on CLAIM_DATE value: (float)
  - CLAIM_ID (value): ELMNT_EV
  - CLAIM_ID (---): 0.00

  "If ELMNT_STATUS (Off), this value is null"

In optional cases, cost control processes can be performed to selected item in order to study this item elements; Then, additional optional fields should be added to each feature to represent actual cost, as:

- ELMNT_AC(currency)(optional): total actual cost of each element. (float)
  "If ELMNT_STATUS (Off), this value is null"

- ELMNT_CV(currency)(optional): cost variance of each item; It is algebraic difference of: (float)
  ELMNT_EV - ELMNT_AC or ELMNT_APRV_EV - ELMNT_AC
  (+)ve value: success, (-)ve value: problem
  "If ELMNT_STATUS (Off), this value is null"

- ELMNT_CPI(optional): cost performance index of each item, it is algebraic division of: (float)
  ELMNT_AC / ELMNT_EV or ELMNT_AC / ELMNT_APRV_EV
  Value<1.00: success, value>=1.00: problem
  "If ELMNT_STATUS (Off), this value is null"

3.8.4 Item Level Tables

After performing these previous calculations at element level, it should transfer summaries to item level. In this level, new tables should be constructed to perform cost control processes, as:

- Actual cost records table
- Cost performance indicators table
- Cost forecasting table

3.8.4.1 Actual Cost Records Table

Accurate records for actual costs have to be performed; this table involves materials, equipment, labours, and other expenditures records, as:

- AC_DATE: the date of actual cost record (date)

- AC_DESCRIPTION: actual cost description. (text)

- AC_VALUE(currency): actual cost value record (float)

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- AC_ITEM_ID: location of actual cost value in what contractual item will be; This value inherited from ITEM_ID (text)

- AC_CLASS: classification of actual cost record according to its type; It can be one of: (text)
  - Materials
  - Equipments
  - Labours
  - Others

3.8.4.2 Cost Performance Indicators Table

This table involves performance indicators; The main data needed to transfer from each feature class (item):

- ITEM_ID: contractual Item number. (text)

- ITEM_DESCRIPTION: contractual Item description. (text)

- ITEM_UNIT: contractual quantity unit. (text)

- UNIT_PRICE(currency): contractual unit price due to contractual currency. (float)

- ITEM_CNTRCT_QUANTITY: contractual quantity of each item; It is the pre-assigned quantity according to contractual documents (float)

- ITEM_CNTRCT_PRICE(currency): contractual price of each item; It is the pre-assigned price according to contractual documents (float)

- ITEM_PLN_QUANTITY: total planed quantity of each item; It is the summations of ELMNT_PLN_QUANTITY fields of each feature class (item) (float)

- ITEM_PLN_PRICE(currency): total planed price of each item, it is the summations of ELMNT_PLN_PRICE fields of each feature class (item) (float)

- ITEM_EV(currency): total earned value of each item, it is the summations of ELMNT_EV fields of each feature class (item) (float)

- ITEM_APRV_EV(currency): total approved earn value of each item, it is the summations of ELMNT_APRV_EV fields of each feature class (item) (float)

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- ITEM_AC(currency): total actual cost of each item, it is the summations of AC_VALUE field from Actual Cost Records table (float)

Now, performance indicators can be calculated, as:

- ITEM_CV(currency): cost variance of each item; It is algebraic difference of: (float)
  ITEM_EV - ITEM_AC or ITEM_APRV_EV - ITEM_AC
  (+)ve value: success, (-)ve value: problem

- ITEM_CPI: cost performance index of each item; It is algebraic division of: (float)
  ITEM_AC / ITEM_EV or ITEM_AC / ITEM_APRV_EV
  Value<1.00: success, value>=1.00: problem

- ITEM_ETC(currency): estimate to completion of each item; It is algebraic difference of: (float)
  ITEM_PLN_PRICE - ITEM_EV or
  ITEM_PLN_PRICE - ITEM_APRV_EV

- ITEM_EAC(currency): estimate at completion of each item; It is the same value of ITEM_PLN_PRICE. (float)
  This field should be compared with ITEM_CNTRCT_PRICE field to check potential overruns.

- ITEM_PLN_PROGRESS: ratio of each item progress according to project plan; It is algebraic division of: (float)
  ITEM_EV / ITEM_PLN_PRICE or
  ITEM_APRV_EV / ITEM_PLN_PRICE

- ITEM_CNTRCT_PROGRESS: ratio of each item progress according to BOQ; It is algebraic division of: (float)
  ITEM_EV / ITEM_CNTRCT_PRICE or
  ITEM_APRV_EV / ITEM_CNTRCT_PRICE

Note: using of ITEM_EV give results to any go-on tasks, while using ITEM_APRV_EV give results only to approved tasks.

3.8.4.3 Cost Forecasting Table

This table involves forecasting data; The main data needed to transfer from each feature class (item):

- ITEM_ID: contractual Item number. (text)

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- ITEM_DESCRIPTION: contractual Item description. (text)
- ITEM_UNIT: contractual quantity unit. (text)
- UNIT_PRICE(currency): contractual unit price due to contractual currency. (float)
- ITEM_CNTRCT_QUANTITY: contractual quantity of each item, it is the pre-assigned quantity according to contractual documents (float)
- ITEM_CNTRCT_PRICE(currency): contractual price of each item, it is the pre-assigned price according to contractual documents (float)
- ITEM_PLN_QUANTITY: total planed quantity of each item, it is the summations of ELMNT_PLN_QUANTITY fields of each feature class (item) (float)
- ITEM_PLN_PRICE(currency): total planed price of each item, it is the summations of ELMNT_PRICE fields of each feature class (item) (float)

Now, forecasting can be calculated, as:

- ITEM_PLN_VARIANCE(currency): variance value of each item according to drawings, it is algebraic difference of: (float)

  ITEM_CNTRCT_PRICE - ITEM_PLN_PRICE

  (+)ve value: surplus, (-)ve value: deficiency

In optional cases, supposed scenarios for quantities changes can be performed to some items in order to study this scenarios; this can be helpful to develop project plans according to changeable work conditions. Then, additional optional fields should be added to check these scenarios, as:

- ITEM_SPS_QUANTITY: supposed quantity of each item; It is an edited field that can be used to test supposes (float)
- ITEM_SPS_PRICE(currency): supposed price of each item; It is algebraic multiplication of: (float)

  ITEM_SPS_QUANTITY * UNIT_PRICE

- ITEM_SPS_VARIANCE(currency): variance value of each item according to supposes; It is algebraic difference of: (float)

  ITEM_CNTRCT_PRICE - ITEM_SPS_PRICE

  (+)ve value: surplus, (-)ve value: deficiency

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3.8.5 Project Level Tables

After performing these previous calculations at item level, it should transfer summaries to project level; in this level, new tables should be constructed to perform cost control processes, as:

3.8.5.1 Project Claims Table

This table involve claims data that are used to preview all claims in the project, it must be sorted according date in order to infer the (S-curve), as:

- CLAIM_ID: claim ID of approved elements by consultant according to contractual documents. (text)
- CLAIM_DATE: the date of claim approval. (date)
- CLAIM_VALUE(currency): approved claim value of each claim; It is editable field (float)
- CLAIM_CMLTV_VALUE(currency): cumulative value of claims according to CLAIM_DATE field (float)
- CLAIM_CMLTV_AC(currency): cumulative value of actual cost at claims date according to CLAIM_DATE field, inherited from Actual Cost Record table (float)
- BENEFIT/LOSS(currency): benefit or loss value that indicate if it can cumulative claims cover cumulative costs or not (float)
  CLAIM_CMLTV_VALUE - CLAIM_CMLTV_AC

By CLAIM_DATE value and both of CLAIM_CMLTV_VALUE and CLAIM_CMLTV_AC values at each date it can be drawn S-curve.

3.8.5.2 Project Cost Evaluation Table

- PRJCT_ID: contractual project number (text)
- PRJCT_NAME: contractual project name (text)
- PRJCT_CNTRCT_PRICE(currency): contractual total price of whole project; It is the pre-assigned price according to contractual documents (float)
- PRJCT_PLN_PRICE(currency): total planed price of whole project; It is the summation of ITEM_PLN_PRICE field from performance indicators table (float)

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- PRJCT_EV(currency): total earned value of whole project; It is the summation of ITEM_EV field from performance indicators table (float)

- PRJCT_APRV_EV(currency): total approved earn value of whole project; It is the summation of ITEM_APRV_EV field from performance indicators table (float)

- PRJCT_AC(currency): total actual cost of whole project; It is the summation of ITEMT_AC field from Cost Performance Indicators table (float)

Now, performance indicators can be calculated, as:

- PRJCT_CV(currency): cost variance of whole project; It is algebraic difference of: (float)
  PRJCT_EV - PRJCT_AC or PRJCT_APRV_EV - PRJCT_AC
  (+)ve value: success, (-)ve value: problem

- PRJCT_CPI: cost performance index of whole project; It is algebraic division of: (float)
  PRJCT_AC / PRJCT_EV or PRJCT_AC / PRJCT_APRV_EV
  Value<1.00: success, value>=1.00: problem

- PRJCT_ETC(currency): estimate to completion of whole project; It is algebraic difference of: (float)
  PRJCT_PLN_PRICE - PRJCT_EV or
  PRJCT_PLN_PRICE - PRJCT_APRV_EV

- PRJCT_EAC(currency): estimate at completion of whole project; It is the same value of PRJCT_PLN_PRICE. (float)
  This field should be compared with PRJCT_CNTRCT_PRICE field to check potential overrun.

Note: using of PRJCT_EV give results to any go-on tasks, while using PRJCT_APRV_EV give results only to approved tasks.

Also, forecasting indicators can be calculated, as:

- PRJCT_PLN_VARIANCE(currency): variance value of whole project according to drawings; It is algebraic difference of: (float)
  PRJCT_CNTRCT_PRICE - PRJCT_PLN_PRICE
  (+)ve value: surplus, (-)ve value: deficiency

In optional cases, supposed scenarios for quantities changes can be performed in order to develop project plans; Then, additional optional fields should be added, as:

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- PRJCT_SPS_PRICE(currency): supposed price of whole project; It is summation of ITEM_SPS_PRICE field from forecasting table in order to test supposes (float)

- PRJCT_SPS_VARIANCE(currency): variance value of whole project according to supposes from forecasting table; It is algebraic difference of: (float)
  PRJCT_CNTRCT_PRICE - PRJCT_SPS_PRICE
  (+)ve value: surplus, (-)ve value: deficiency

Then, progress indicators can be calculated as:

- PRJCT_ITEMS_ON: number of contractual items that have been implemented or are going on, any item that has ITEM_EV value are considered in this field (integer)

- PRJCT_ITEMS_YET: number of contractual items that are not start to implement, any item that has no ITEM_EV value are considered in this field (integer)

- CLAIMS_APRV: number of approved claims; It is counting of CLAIM_ID values inherited from project claims table (integer)

- CLAIMS_TOTAL(currency): total claims value of project; It is summation of CLAIM_VALUE field from project claims table (float)

- PRJCT_PLN_PROGRESS: ratio of whole project progress according to project plan; It is algebraic division of: (float)
  PRJCT_EV / PRJCT_PLN_PRICE or
  PRJCT_APRV_EV / PRJCT_PLN_PRICE

- PRJCT_CNTRCT_PROGRESS: ratio of whole project progress according to BOQ; It is algebraic division of: (float)
  PRJCT_EV / PRJCT_CNTRCT_PRICE or
  PRJCT_APRV_EV / PRJCT_CNTRCT_PRICE

Note: using of PRJCT_EV give results to any go-on tasks, while using PRJCT_APRV_EV give results only to approved tasks.

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3.8.6 Visualization

The most important advantages of the developed system is its capabilities to show outputs in visual methods that can give easy way to realize facts easily. At each control level there are several information that is needed to show.

3.8.6.1 Element (Task) Level Visualization

After editing of each of previous tables, it can be viewed the drawings in data frame window that involve project features. The basic idea is to view drawings in interactive maps, these maps can show easily the required indicators on project elements by using these methods: map legends, labels, identify and query orders.

3.8.6.1.1 Map Legends

Pre-designed legends can be used to distinguish elements at element level management; ArcGIS can offer this ability very easy to so many kinds of dynamic legend due to data in attributes tables, the developed system concern on the following legends:

- Progress legend: it depends on ELMNT_STATUS value:
  - ELMNT_STATUS (Yes): specified colour
  - ELMNT_STATUS (On): green colour
  - ELMNT_STATUS (No): black colour
  - ELMNT_STATUS (Off): gray colour

- Claim legend: it depends on CLAIM_ID value:
  - CLAIM_ID (value): unique value colour
  - CLAIM_ID (---): black colour
  - CLAIM_ID (null): gray colour

In optional cases, cost control indicators can be perform to selected item in order to study this item elements; Then, additional optional legends should be used to represent cost control indicators, as:

- CV legend: it depends on ELMNT_CV value:
  - ELMNT_CV (+ve value): green colour
  - ELMNT_CV (0 or –ve value): red colour

- CPI legend: it depends on ELMNT_CPI value:
  - ELMNT_CPI (value<1.00): green colour
  - ELMNT_CPI (value>=1.00): red colour

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3.8.6.1.2 Labels

Labels can be used to mark elements at element level management; ArcGIS can offer this ability to any data in attributes tables, the developed system concern on the following labels:

- ELMNT_ID
- ITEM_ID
- ELMNT_PLN_QUANTITY
- ELMNT_PLN_PRICE(currency)
- ELMNT_EV
- ELMNT_APRV_EV

3.8.6.1.3 Identify Orders

Identify orders can be used to show all details of an objected element at element level management. ArcGIS can offer this ability to show details directly on map, the developed system can use this ability to inform user about details he search.

3.8.6.1.4 Query Orders

Query orders can be used to select aimed elements at element level management. ArcGIS can offer this ability to select any feature that has specified certain data in attributes tables, the developed system can use this ability to inform user which elements he search among all other elements in map.

3.8.6.1.5 Layouts

Layouts are a kind of ArcGIS documents which provide final map view. Each layout organizes a list of features and graphics objects by formal form. It can then show those objects on screen, send them to a printer, and send them to one of several standard graphics file formats. It is useful to use layouts in reports to illustrate control status of project components.

3.8.6.2 Item Level Visualization

This level depends on control tables that give lots of information, it can be shown by charts in order to realize information easily, as:

3.8.6.2.1 Actual Cost Records Charts

- According to AC_DATE, AC_VALUE can be shown in chart.
- According to AC_ITEM_ID, AC_VALUE can be shown in chart.
- According to AC_CLASS, AC_VALUE can be shown in chart.

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3.8.6.2.2 Cost Performance Indicators Charts

- According to ITEM_ID, several charts can be shown, as:
  - UNIT_PRICE
  - ITEM_CNTRCT_QUANTITY
  - ITEM_CNTRCT_PRICE
  - ITEM_PLN_QUANTITY
  - ITEM_PLN_PRICE
  - ITEM_EV
  - ITEM_APRV_EV
  - ITEM_AC
  - ITEM_CV
  - ITEM_CPI
  - ITEM_ETC
  - ITEM_EAC
  - ITEM_PLN_PROGRESS
  - ITEM_CNTRCT_PROGRESS

3.8.6.2.3 Cost Forecasting Charts

- According to ITEM_ID, several charts can be shown, as:
  - UNIT_PRICE
  - ITEM_CNTRCT_QUANTITY
  - ITEM_CNTRCT_PRICE
  - ITEM_PLN_QUANTITY
  - ITEM_PLN_PRICE
  - ITEM_PLN_VARIANCE
  - ITEM_SPS_QUANTITY
  - ITEM_SPS_PRICE
  - ITEM_SPS_VARIANCE

3.8.6.3 Project Level Visualization

In addition, this level depends on control tables that give lots of information, it can be shown by charts in order to realize information easily, as:

3.8.6.3.1 Project Claims Charts

- According to CLAIM_ID, several charts can be shown, as:
  - CLAIM_VALUE
  - BENEFIT/LOSS

- According to CLAIM_DATE, several charts can be shown, as:
  - CLAIM_VALUE
  - BENEFIT/LOSS

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- According to CLAIM_DATE, S-curve chart can be shown to:
  - CLAIM_CMLTV_VALUE
  - CLAIM_CMLTV_AC

3.8.6.3.2 Project Cost Evaluation Report

This is the final information that inherited from all previous processes; it can be reviewed and organized in simple report.

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Chapter Four

System Implementation

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4.1 Introduction

System implementation depends on applying the developed system on real projects to insure that the system can give its advantages, it is good chance to get experience in order to discover strength and weakness points; as mentioned in methodology, System validation is an important part of this research.

According to the methodology, it has to use documents of completed projects to restudy these documents, applying system systematically, and then get results.

4.2 Short Comes

Through searching for real projects, several problems are faced, as:

- Contractors consider that their data are secrets; then, they reject to give any documents.
- Only few consultants give some helps about projects documents, poor data can be gathered because of secret nature of these projects according to them.
- Gathered documents are only primary drawings and BOQ; No claims data, no actual cost records, and no systematic shop drawings.
- These drawings are prepared without coordinate system; location and accurate direction are missing; only scale can be checked.
- Poor drawing preparation is clear, poor details can be gathered and understood; According to consultants, projects drawing of municipalities are often poor prepared because of quick preparing and poor skills, they always depend on contractors shop drawings.
- The gathered projects are limited scope, it is limited projects for developing small neighbourhoods; some of them for paving only, others for sewage or water or gardening only; unfortunately, it is no possible to get one compatible project that can involve these items.

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4.3 Project Description

4.3.1 Project Scope

The case study project is developing a street of 900 meter in Gaza city, the developing aims to construct main infrastructure for this street that contains following works:

1) Road construction works
2) Sewage line works
3) Water line works

4.3.2 Site Location

The project located in Al-Sabra neighbourhood southern of Gaza city, "Al-Mojama' street" is selected as case study. Figure 4.1 illustrates the general location of the case study project in Gaza City.

Figure 4-1 Case study location

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4.3.3 Input Data

4.3.3.1 BOQ

Table 4-1 Project BOQ

No.	Item	Unit	Quantity	Unit Price ($)	Item Price ($)
1	**Road Construction Works**				
1.1	Levelling of the existing road …	M^2	11900	1.00	11900.00
1.2	Crushed debris layer of 25 cm …	M^2	9000	12.00	108000.00
1.3	Ditto but 10 cm …	M^2	3000	7.00	21000.00
1.4	Concrete blocks (Interlock) 6 cm …	M^2	3000	15.00	45000.00
1.5	6cm 3/4" asphalt …	M^2	9000	17.00	153000.00
1.6	Curb stone (15×30×100) cm …	M	1800	18.00	32400.00
1.7	Reinforced Concrete Beam …	M^3	9	260.00	2340.00
1.8	Steel Handrail …	M	150	20.00	3000.00
2	**Sewage System Works**				
2.1	Circular manhole 1.00 m …	No.	31	500	15500.00
2.2	250mm UPVC pipes (SN8) …	M	290	48.00	13920.00
2.3	Ditto but 200mm …	M	600	26.00	15600.00
3	**Water System Works**				
3.1	Circular manhole of 0.80 m …	No.	16	450.00	7200.00
3.2	110 mm UPVC pipes …	M	900	25.00	22500.00
3.3	Gate valve 110 mm 16 bar …	No.	2	150	300.00
	Summation				**451660.00**

4.3.3.2 Drawings

CAD drawings of project are re-prepared to be suitable for exporting to ArcGIS geodatabase format; several layers are constructed to represent elements of each contractual item.

In addition, centreline points at each 20 meter are considered as fixed marks that are the base for scalable elements segmentation, these points are represented by points.

A layer of neighbourhood streets also is presented by polylines that show streets among parcels, this layer is considered as background layer.

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4.4 Modelling The Project in System

4.4.1 Coordinate System

According to municipality of Gaza systems, the coordinate system that is used in all municipality applications is New Israeli Grid coordinate system that is known as Israeli Transverse Mercator (ITM), this is metric projection that is adopted by GIS department. In this case study, this coordinate system should be used. Figure 4.2 illustrates the chosen coordinate system at ArcGIS.

New Israeli Grid parameters(ArcGIS):

Parameter	Value
Projection	Transverse Mercator
False Easting	219529.584000 m
False Northing	626907.390000 m
Central Meridian	35.204517 (35° 12' 16.2612")
Latitude of Origin	31.734394 (31° 44' 03.8184")
Scale factor	1.000007
Linear Unit	Meter
Geographic Coordinate System	GCS Israel
Angular unit	Degree (0.0174532925199433299)
Datum	Datum of Israel
Spheroid	GRS 1980
Semi-major Axis (a)	6378137.0000000000000 m
Semi-minor axis (b)	6356752.3141403561000 m
Flattening (f) = (a-b)/a	0.003352810681182
Eccentricity (e) = $(2f-f^2)^{0.5}$	0.081819191042816
Focal Distance = e*a	521854.009700253 m
To WGS84	Geocentric Translation dx= -48.00, dy= 55.00, dz= 52.00

Source: ArcGIS software v.10

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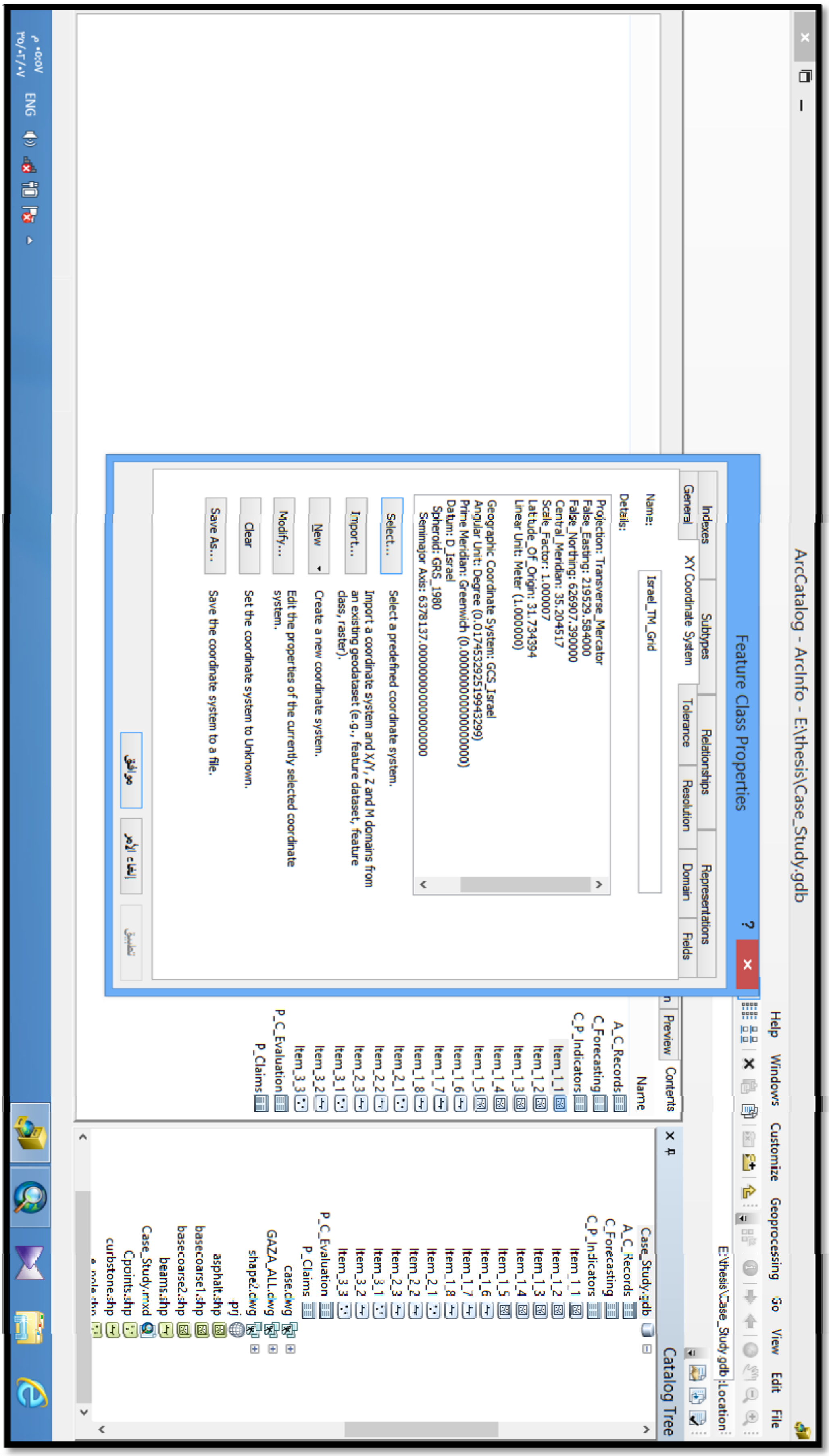

Figure 4-2 Coordinate system

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4.4.2 Drawings Re-preparing

Each layer re-prepared as following:

- Unity unit items (item 2.1: sewer manholes, item: 3.1 water manholes, item 3.3: gate valves) are represented by point elements, each in its special layer.
- Length unit items (item 1.6: Curb stone, 1.8: handrail, item 2.2: 250mm sewer pipes, item 2.3: 200mm sewer pipes, item 3.2: 110mm water pipes) are represented by polyline elements, each in its special layer.
- Area unit items (item 1.1: levelling sub-base layer, item 1.2: 25cm crushed debris, item 1.3: 10cm crushed debris, item 1.4: 6cm Interlock, item 1.5: 6cm asphalt) are represented by polygon elements, each in its special layer.
- Volume item (item 1.7: concrete beams) is represented by polyline elements in its special layer, in order to calculate volume in ArcGIS feature class attributes.

4.4.3 Geodatabase Constructing

In ArcGIS10 package, ArcCatalog10 is management tool for ArcGIS, by ArcCatalog it can be constructed needed geodatabase that contains all feature classes and tables of the system, the required fields of each feature class or table can be constructed according to system concepts that are mentioned previously in chapter four; ArcCatalog can set coordinate system for each feature class; Then, ArcMap10 can be considered as main window of system. Figure 4.3 show main feature classes and tables that are constructed by Arc Catalog.

In ArcMap window, by adding the pre-constructed geodatabase, it can be viewed all project components on screen. It is necessary to set data frame coordinate system to selected system to ensure true calculations for elements geometry according to their units.

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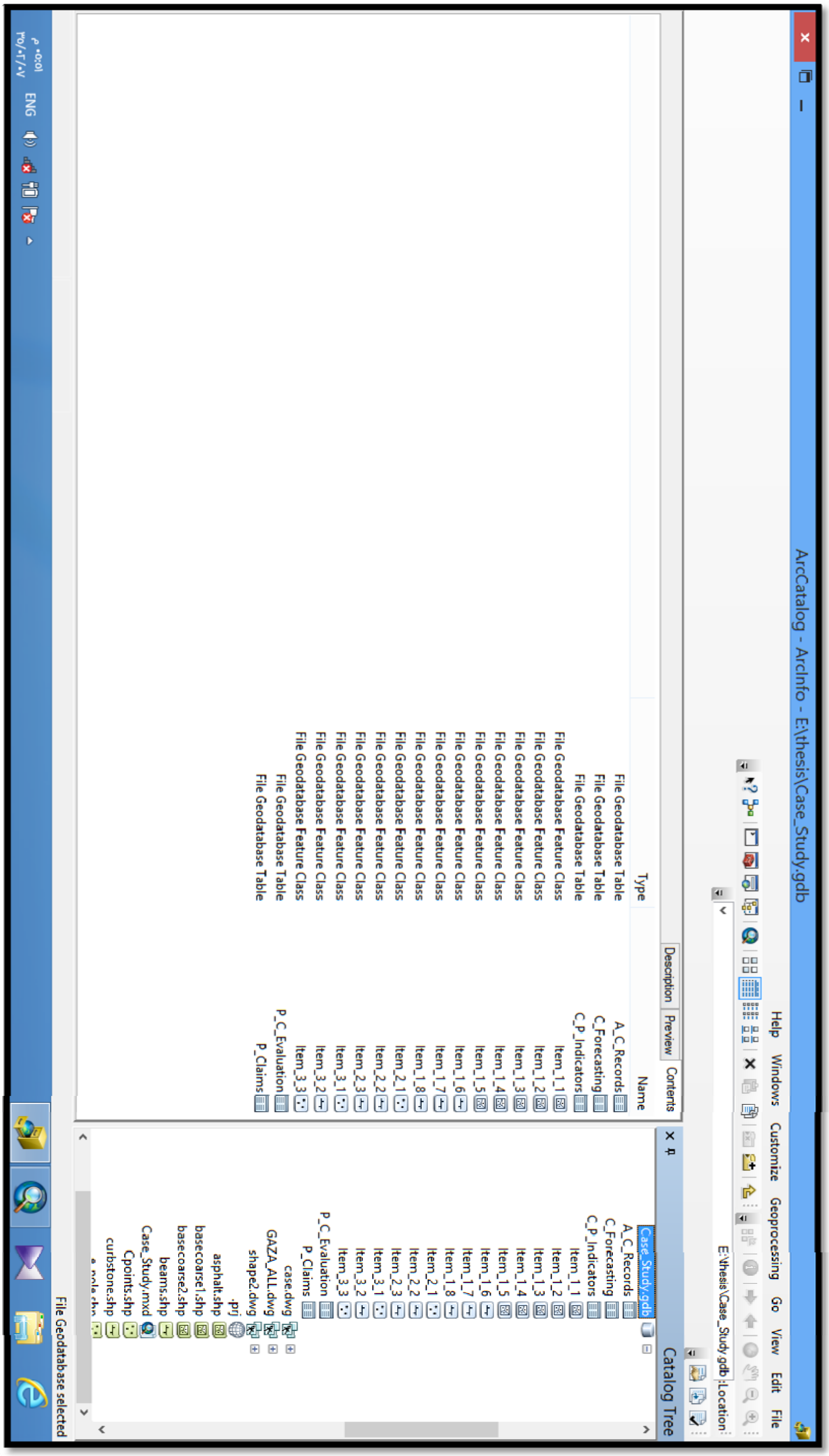

Figure 4-3 Constructing geodatabase

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4.5 Applying The System

4.5.1 At Project Start

4.5.1.1 Element (Task) Level

ArcMap window is the main window of application; Table Of Content (TOC) on side show the feature classes that model the physical components. Data frame shows the graphical model that can be zoomed for more clear view. Each feature class has its attributes that document the needed data. Figures 4.4, 4.5, 4.6 and 4.7 illustrate these steps.

At the beginning of data collection, ArcMap can calculate geometry properties that are used to perform quantity surveying very accurately. It is very important to note any differences between projection unit and contractual unit; ArcMap capabilities offer the ability to calculate geometry in several units as needed.

It is very useful to show data labels on elements that can give quick information on the view; in this example, elements prices can be shown, and any other information can be shown by same way. In addition, identifying complete information about specified element can be performed by identify order; any element can be identified very easy. Also, charts for any information can be produced by chart wizard; in this example, simple comparison between contractual and planed prices can be shown very easy, it can give indication about convergence or divergence between contractual prices (BOQ) and planned prices (drawings). Figures 4.8, 4.9 and 4.10 illustrate these steps.

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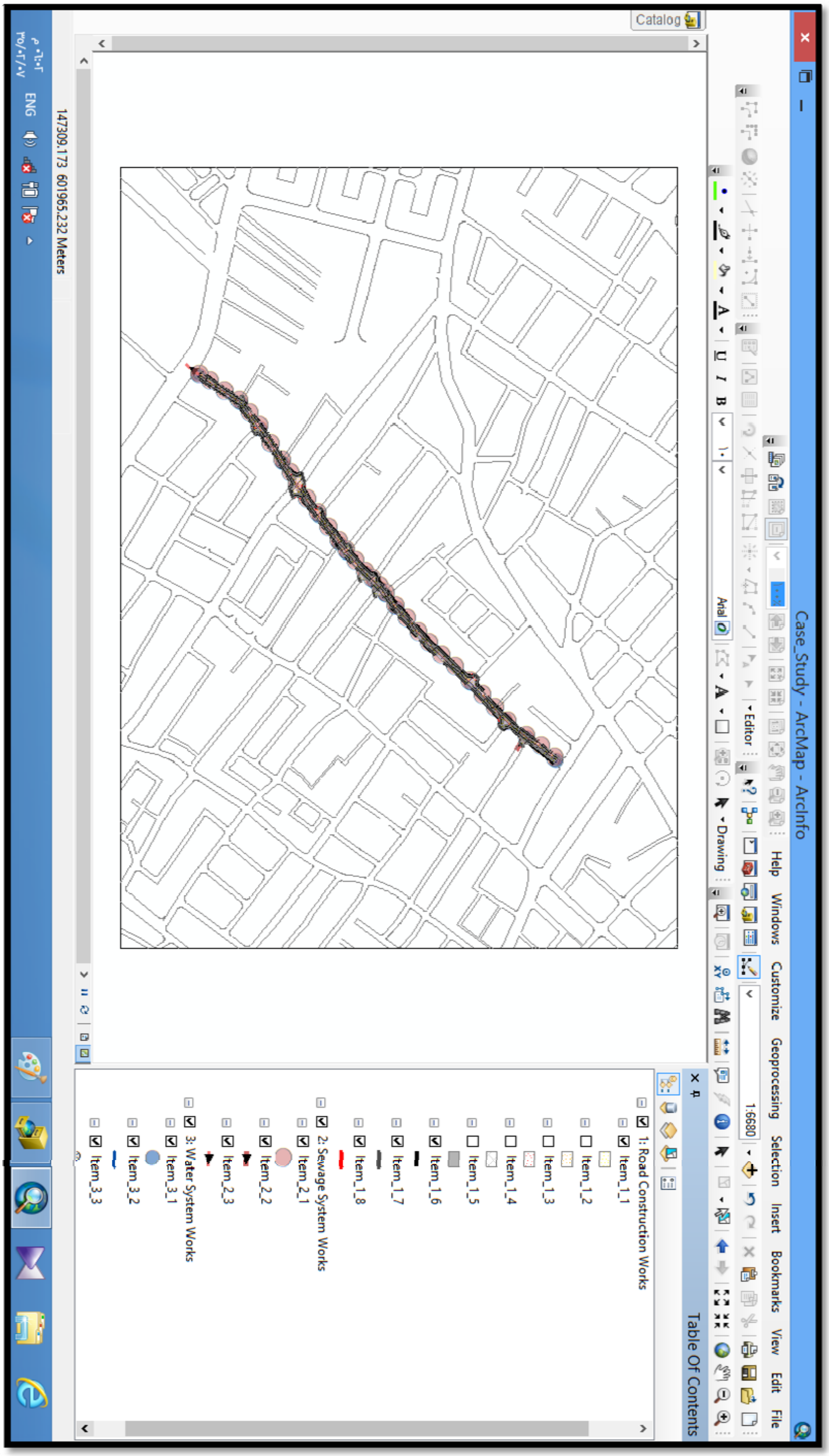

Figure 4-4 System main window

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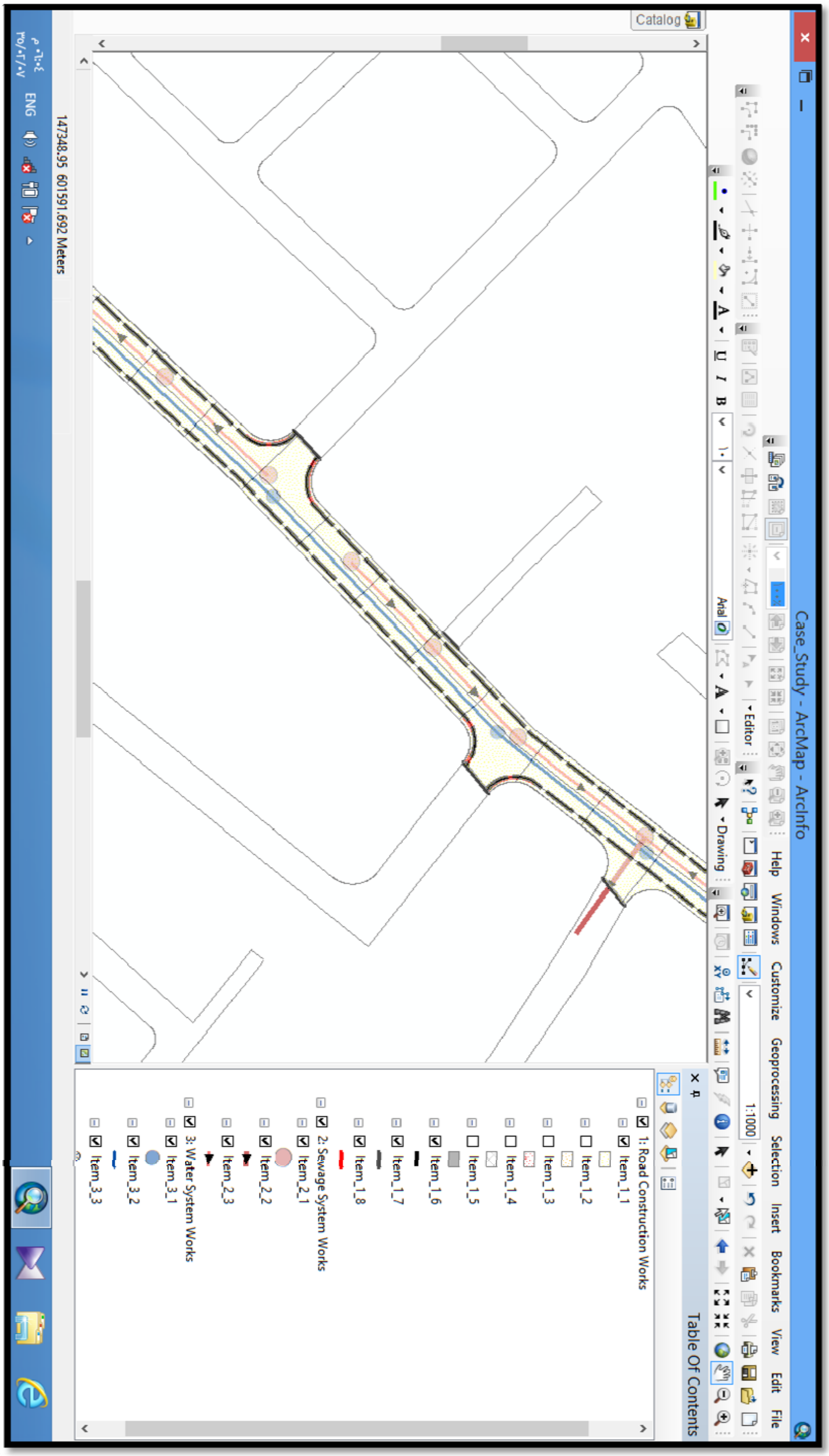

Figure 4-5 Zoomed view of application

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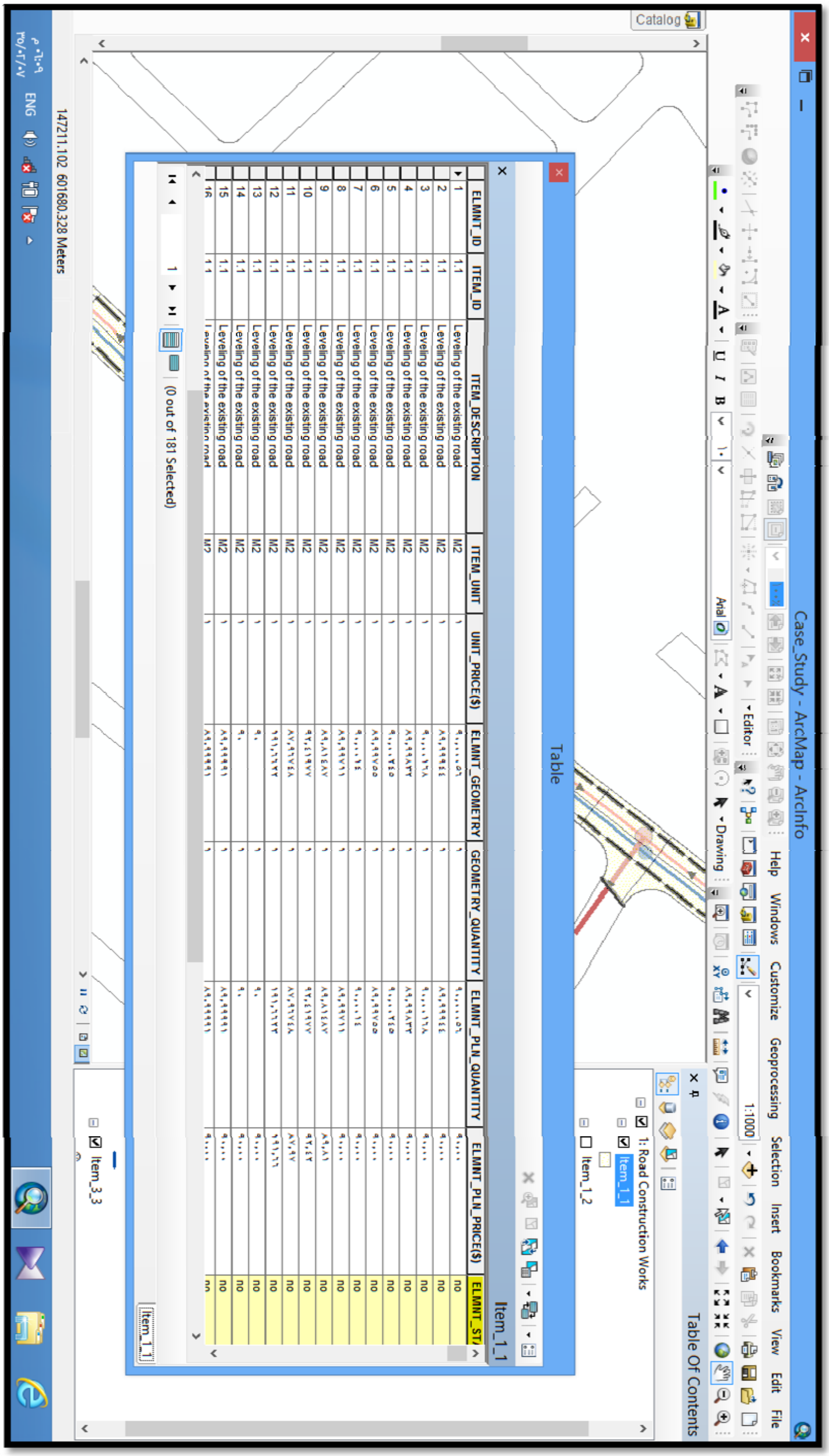

Figure 4-6 Feature class attributes

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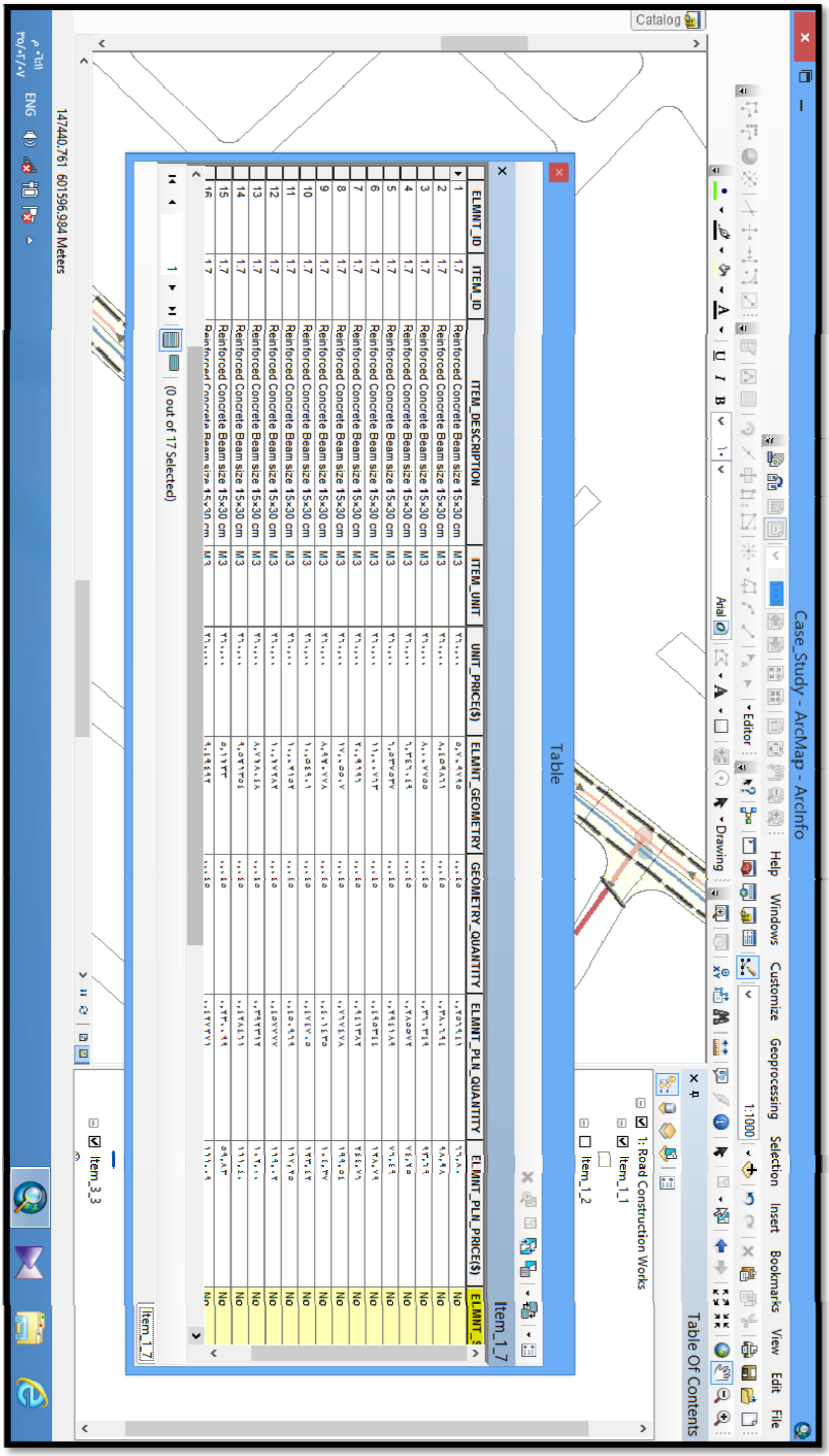

Figure 4-7 Elements data

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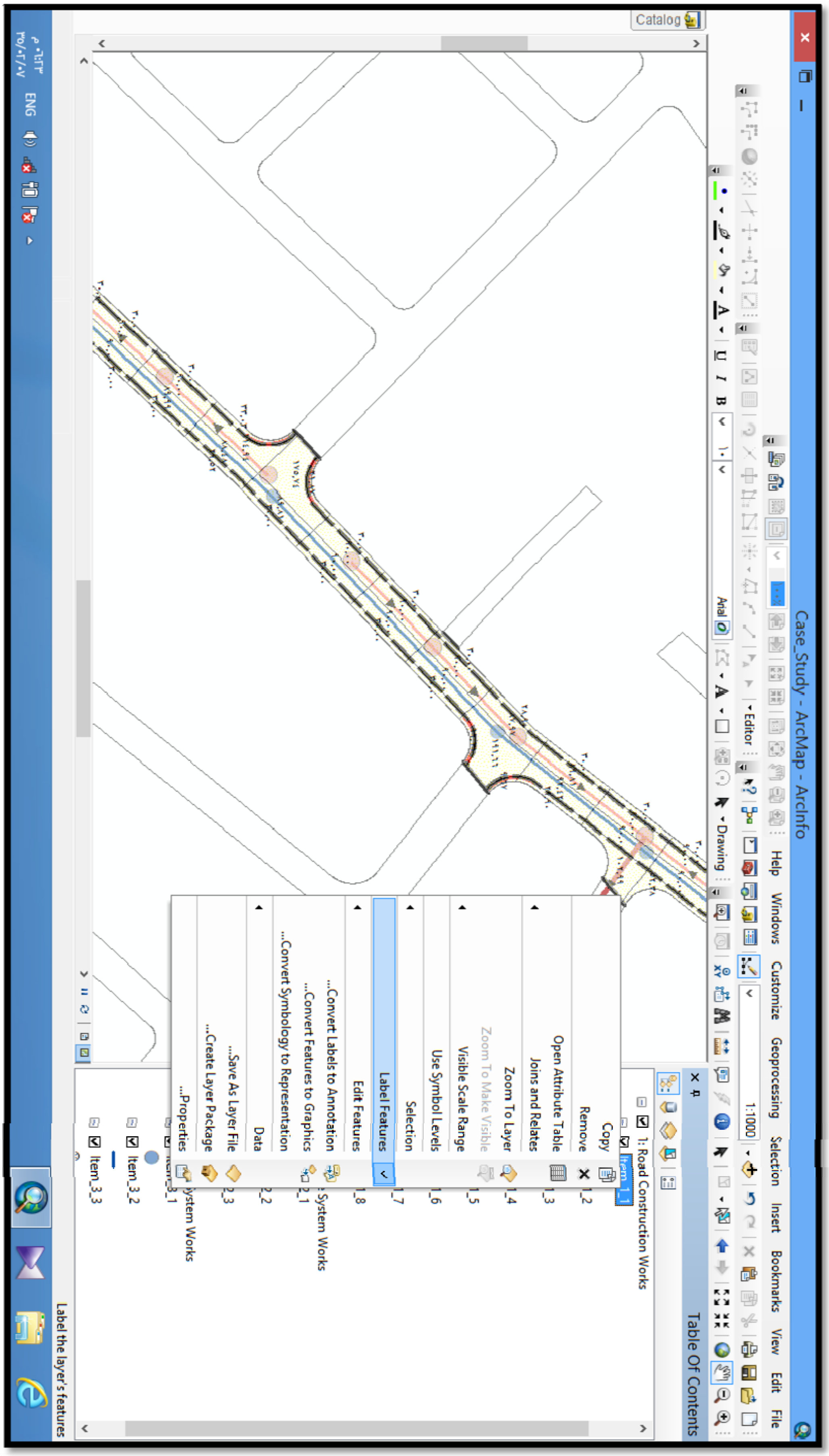

Figure 4-8 Labeling elements

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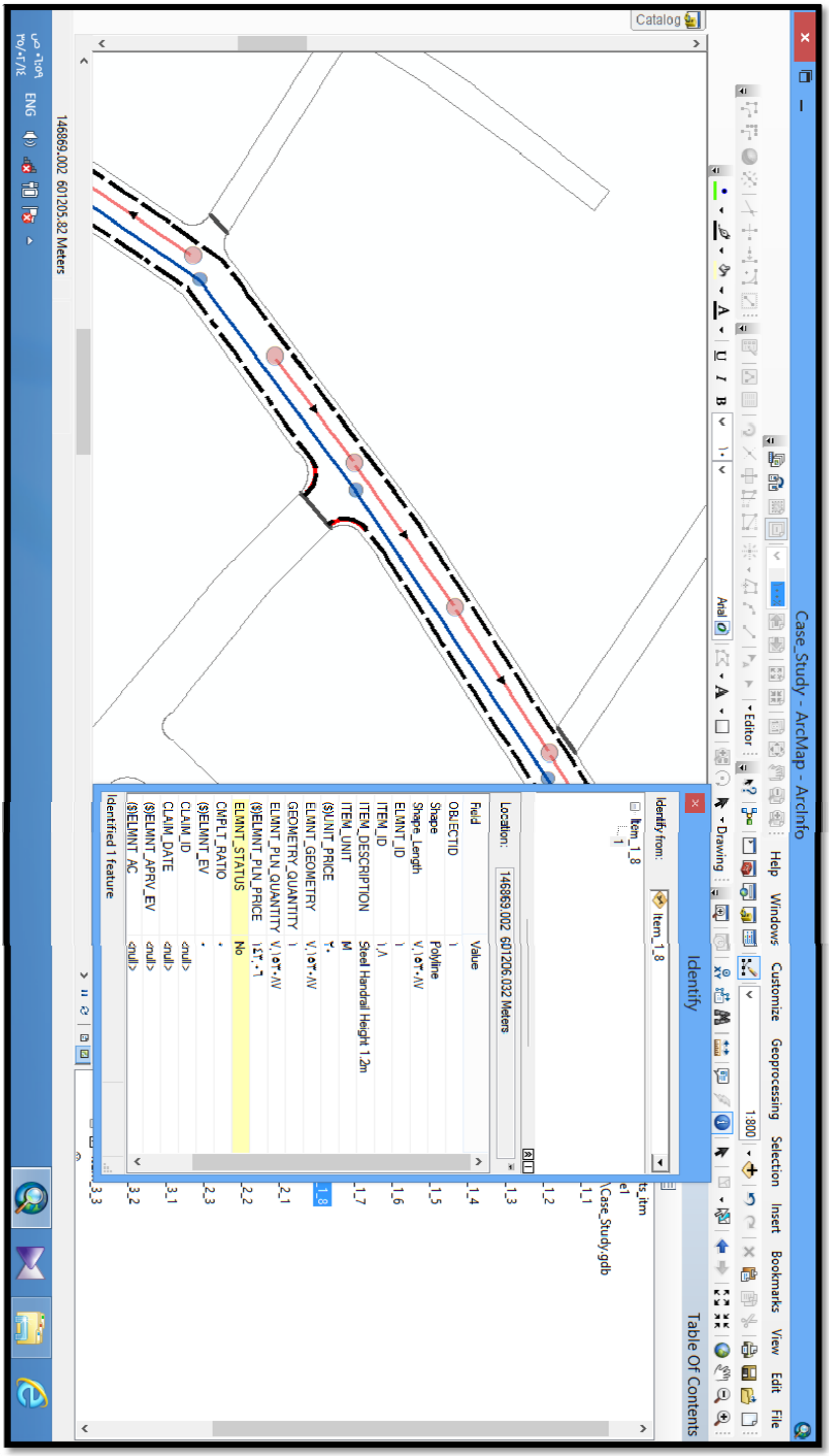

Figure 4-9 Identifying elements

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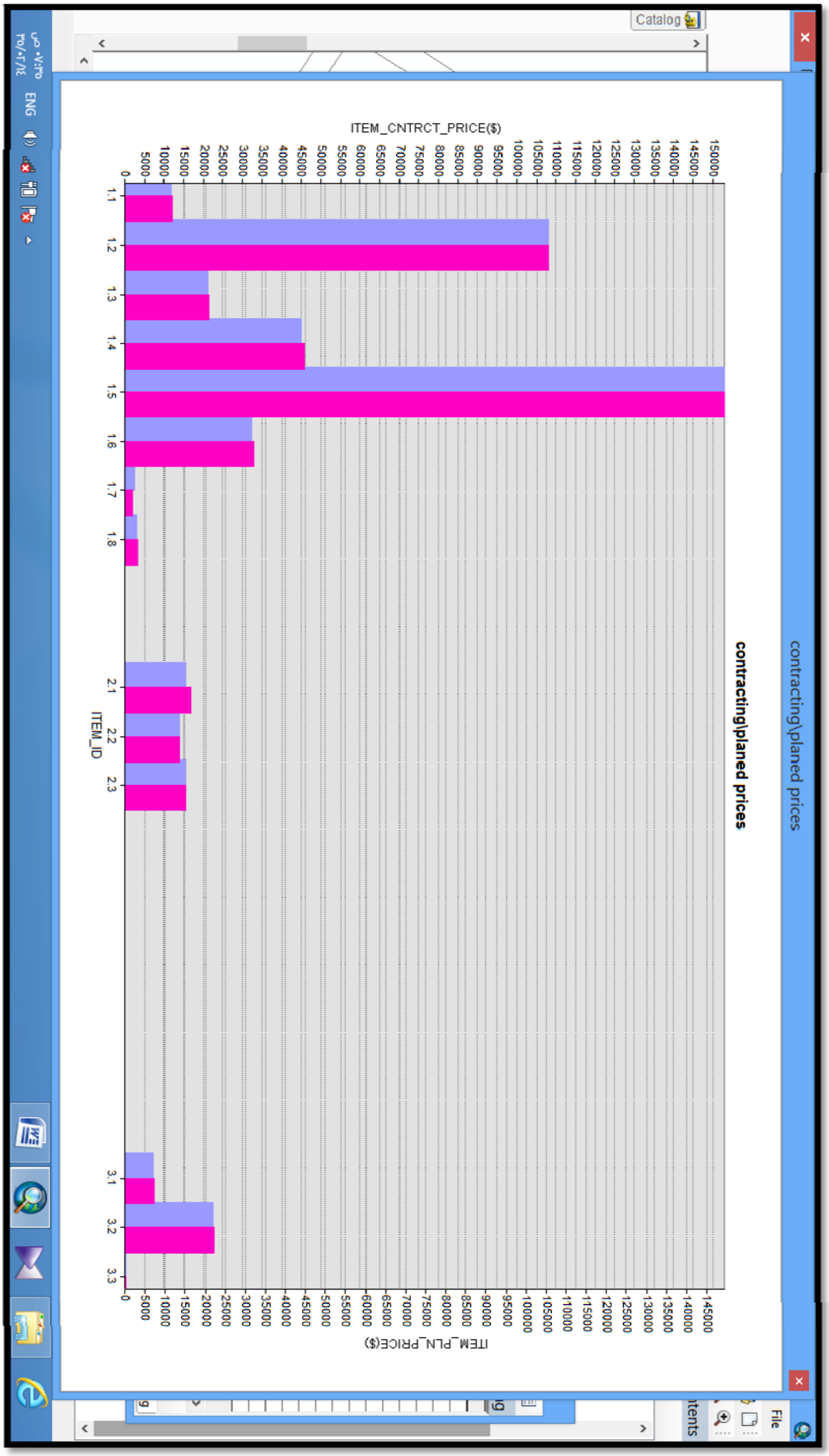

Figure 4-10 Example charts: contractual prices vs. planned prices of project items

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4.5.1.2 Item Level

Summarized data from feature classes should be used in item level. At the project start period, the main data needed is primary quantity surveying from each item feature class.

At the beginning of project, Actual Cost Records table is still empty; few data can be gathered like ponds, insurances, mobilization expenditures.

About Cost Performance Indicators Table, only basic data can be gathered from summarizing feature classes, while other fields are still empty.

About Cost Forecasting table, on contrast with Cost Performance Indicators table, most fields have its data that can be gathered from summarizing feature classes, only few other fields are still empty.

At the beginning of project, it can be known any surpluses or deficits for each contractual item by Cost Forecasting table, while Cost Performance Indicators table needs more information that should gathered during implementation.

Figures 4.11, 4.12 and 4.13 illustrate these tables.

4.5.1.3 Project Level

At project level, short summary for all items can be summarized then input to Project Cost Evaluation table; at the beginning of project, some fields are still empty; Also, Project Claims table is still empty; then, it can be filled by data after implementation of project later. Figure 4.14 illustrate these data.

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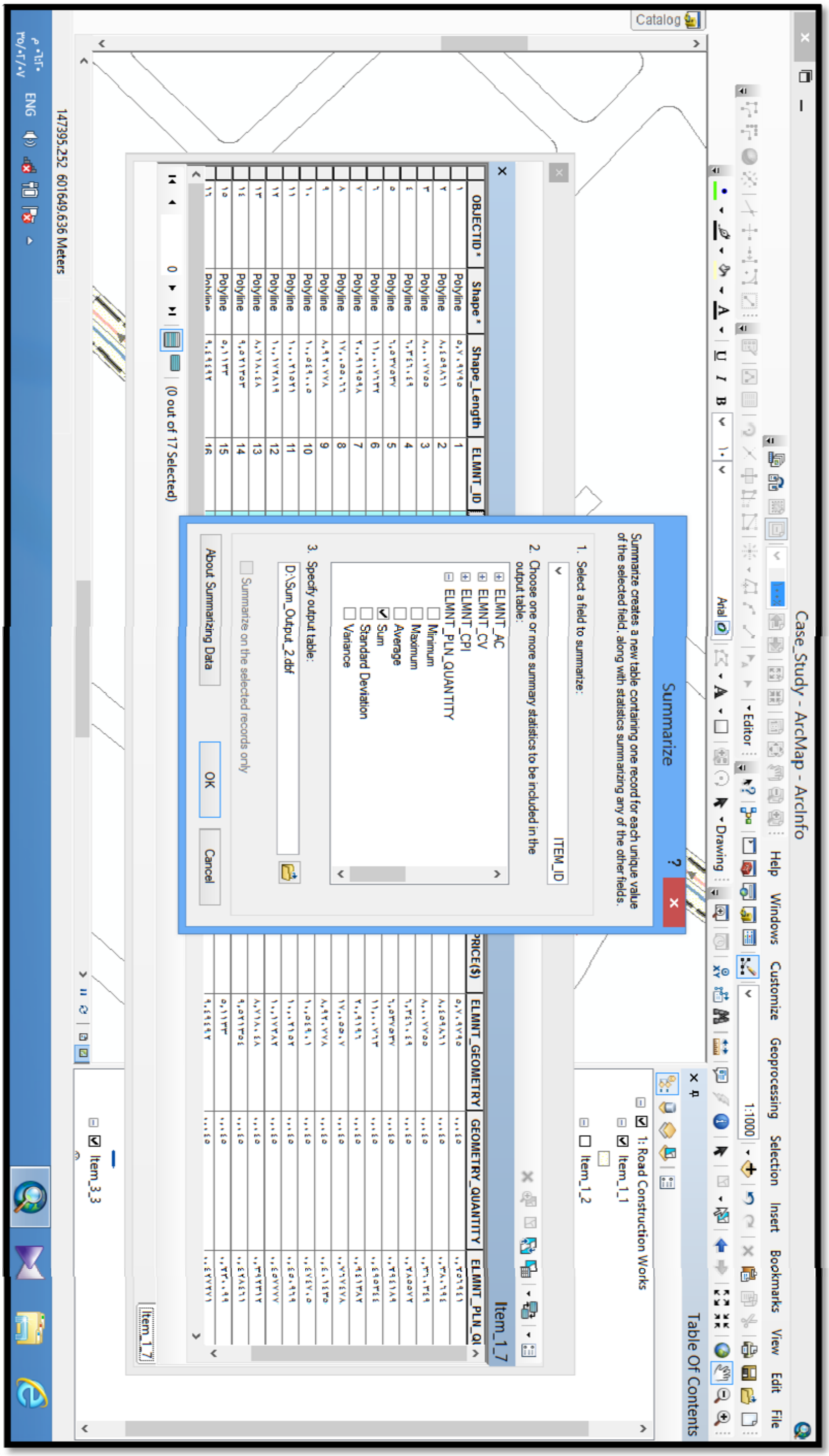

Figure 4-11 Summarizing data

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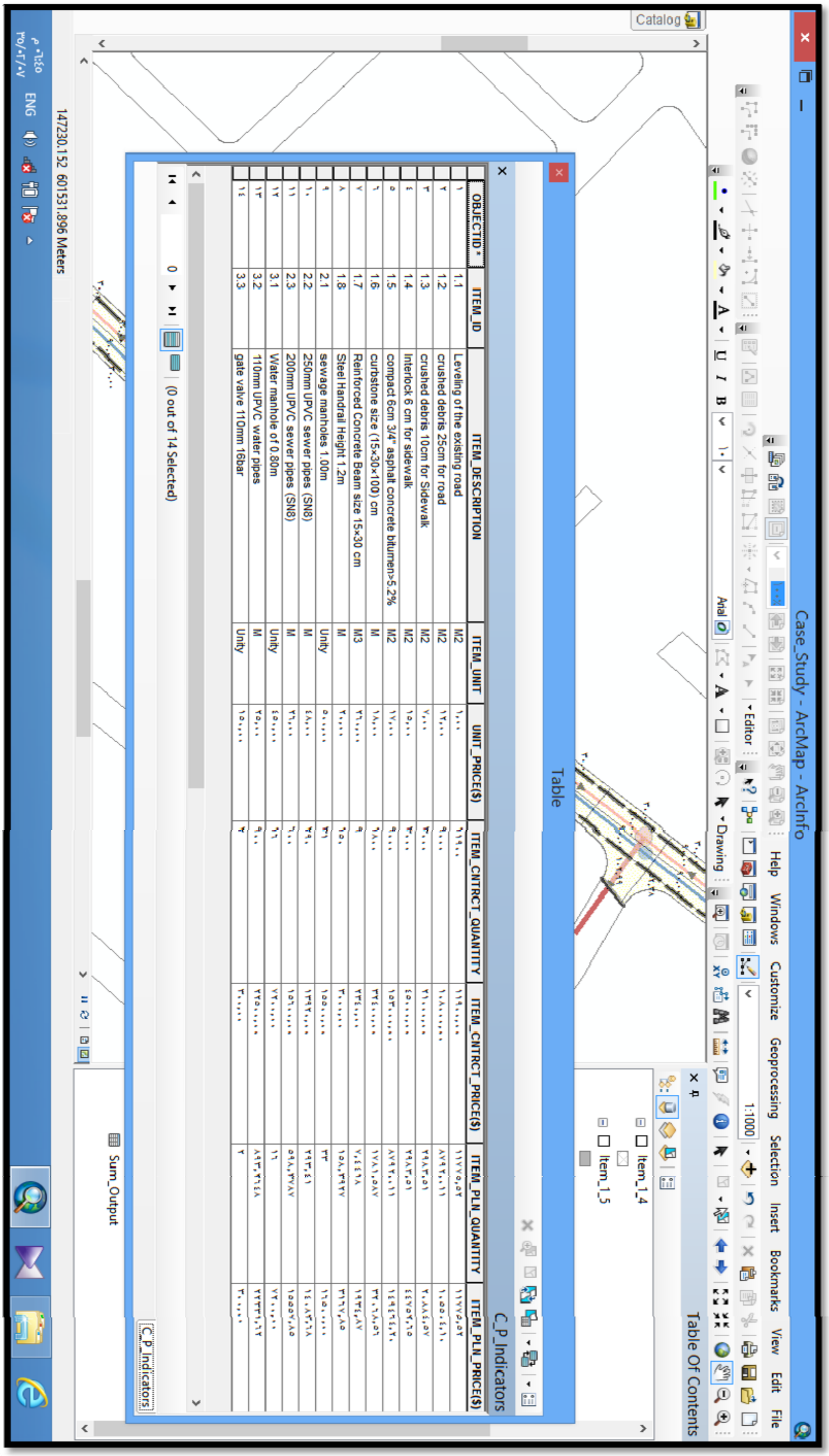

Figure 4-12 Cost performance indicators table

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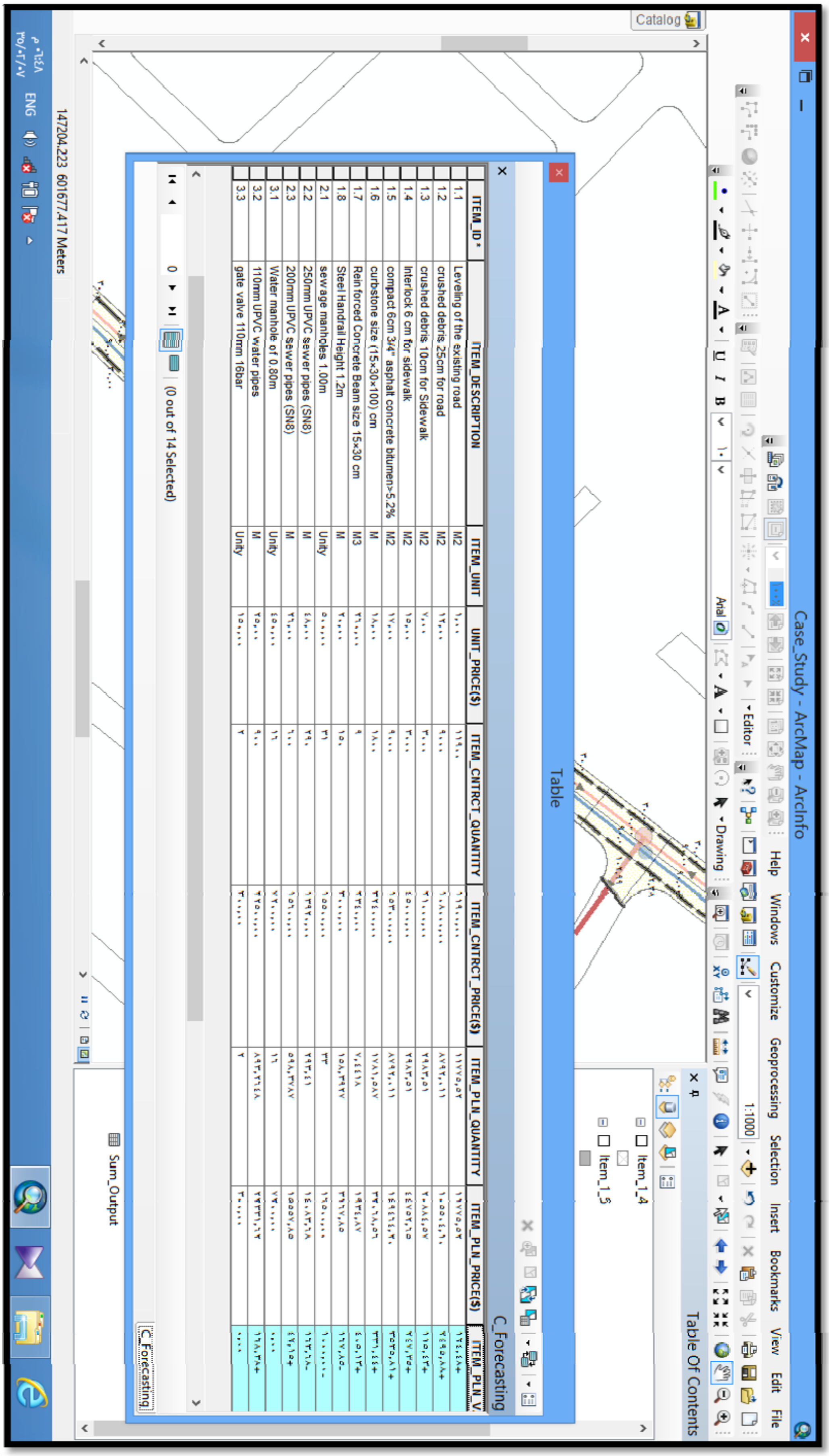

Figure 4-13 Cost forcasting table

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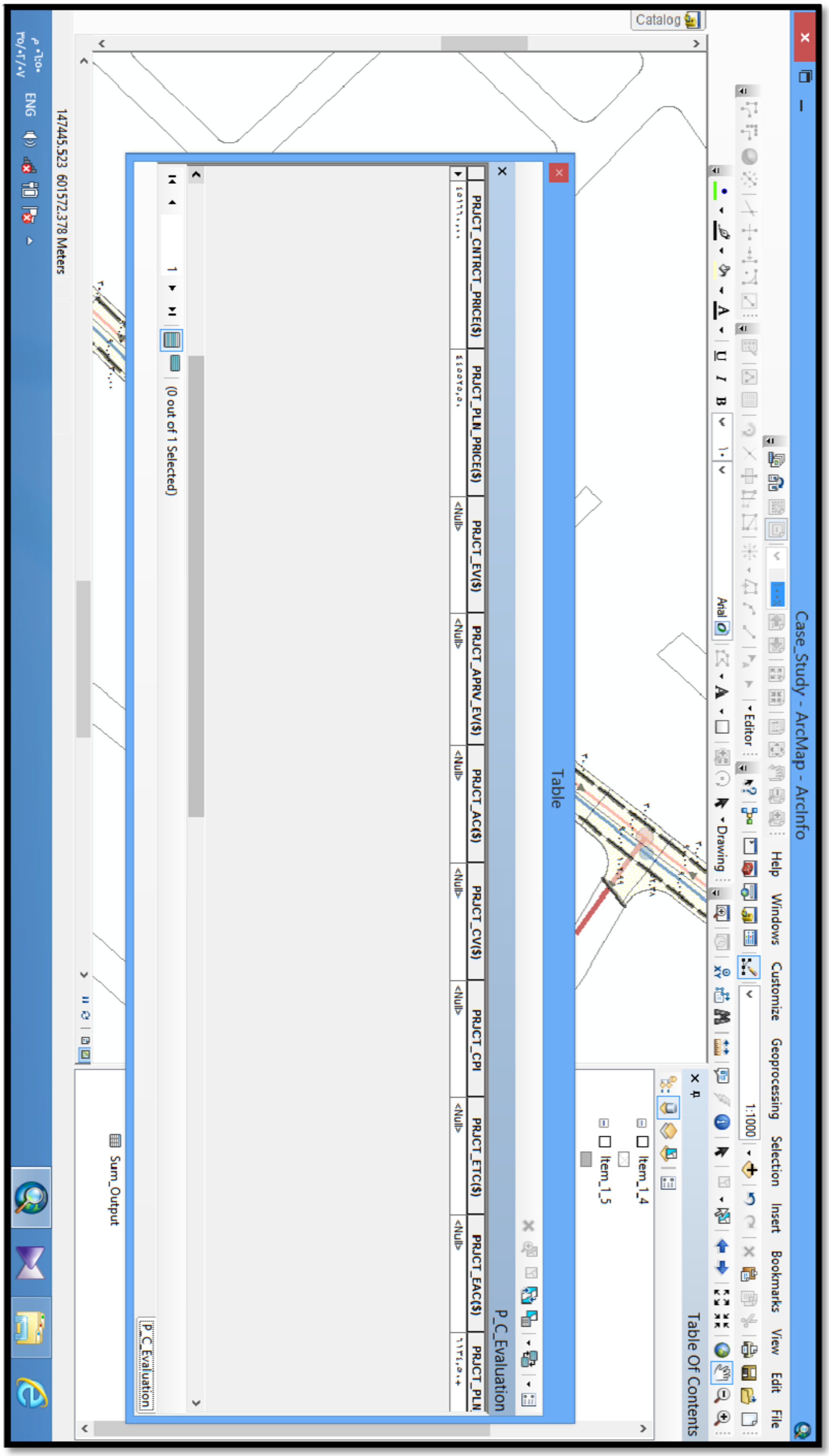

Figure 4-14 Project cost evaluation table

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4.5.2 Project Implementation

4.5.2.1 Element (Task) Level

At project implementation, the main input data for each feature class is implementation data, ELMNT_STATUS fields must be refreshed in order to specify which elements are preformed or underperforming; According to this information, earned values can be calculated; then, cost performance indicators can be calculated and shown in tables or charts.

Also, any element that is claimed can have its claim information, claim ID and date can be recorded, then Approved earned value can be calculated to help user for indentifying which elements claimed or not claimed yet. Figure 4.15 illustrates these data.

4.5.2.2 Item Level

At implementation period, actual cost records have to be filled in order to be used later for Cost Performance Indicators table, each record should be allocated to specified item in order to calculate cost performance indicators and track items one by one. In addition, these records can be classified into classes in order to understand cost type weights.

About Cost Performance Indicators table, additional fields can have its data, according to summarized data from feature classes. About Cost Forecasting table, it is still without changes, only if there is any change of work plans, then it can be used to study this change. Figures 4.16 and 4.17 illustrate these data.

4.5.2.3 Project Level

By implementation, claims should be raised and Project Claims table is started to be filled, by recording several claims and actual costs from item level tables, then it can be drawn the famous (S-curve) by chart.

In addition, short summary for all items can be summarized then input to Project Cost Evaluation table; at implementation of project, all fields have its data. Figures 4.18, 4.19, 4.20and 4.21 illustrate these data.

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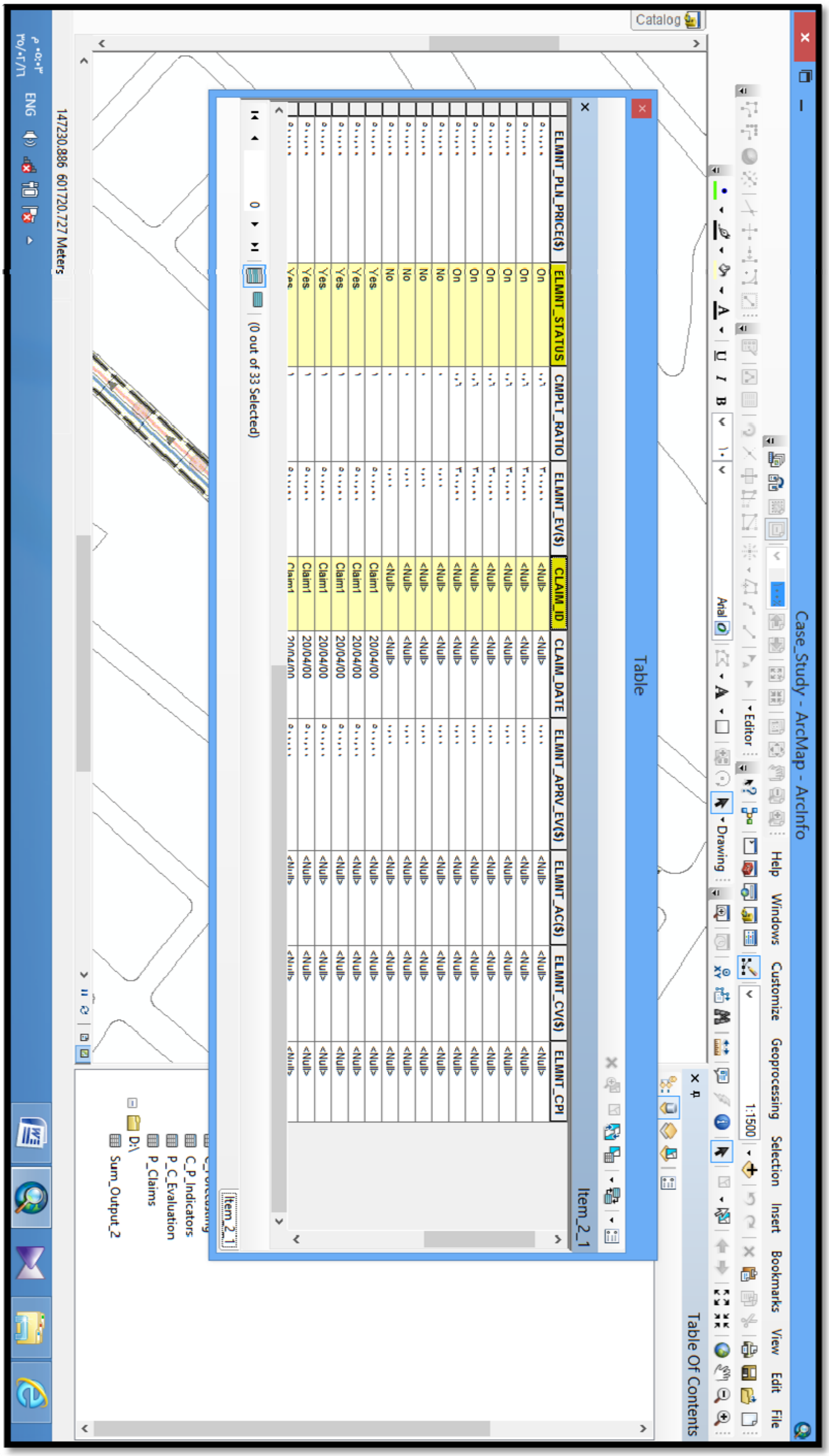

Figure 4-15 Elements implementation

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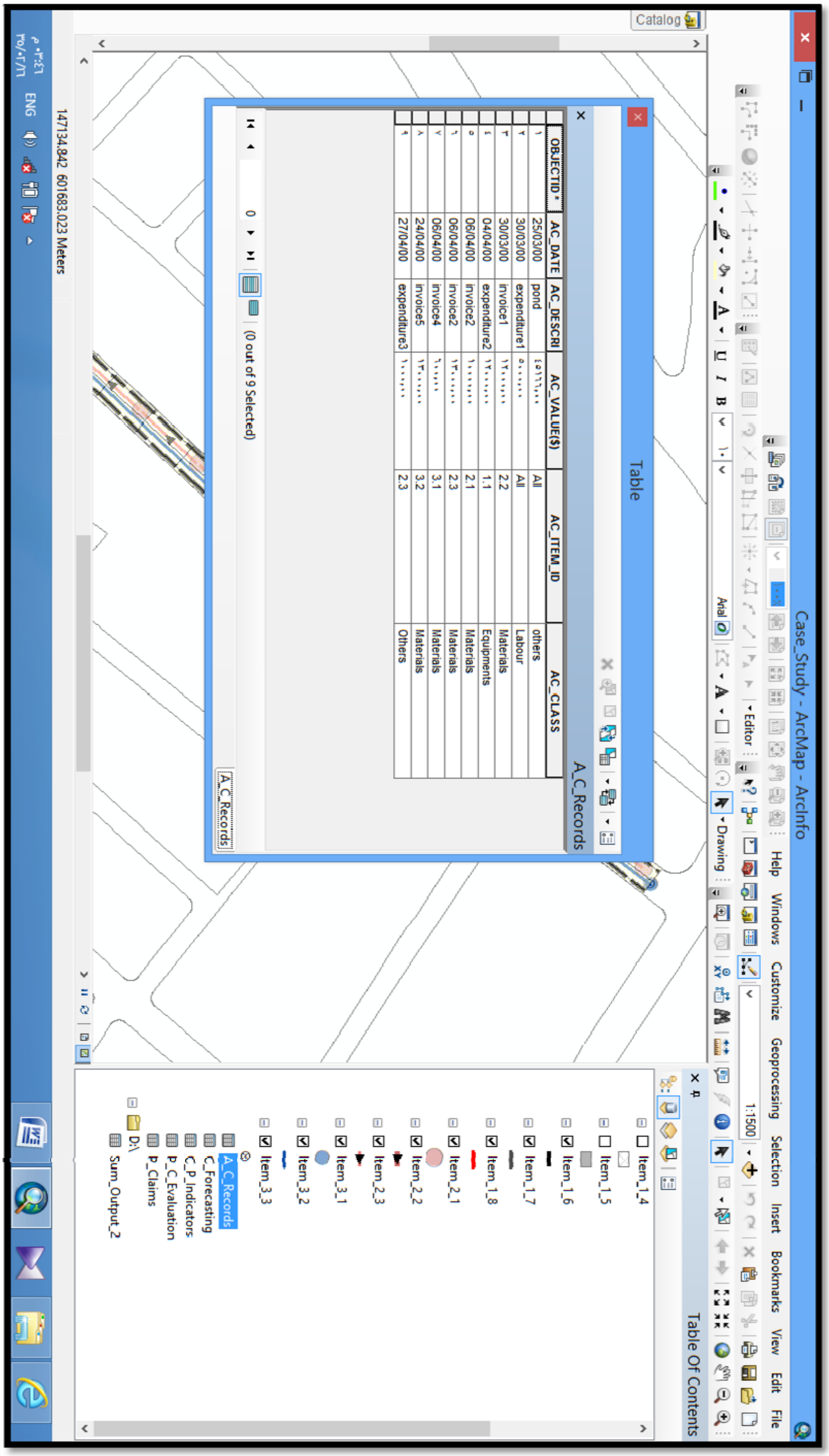

Figure 4-16 Actual cost records table

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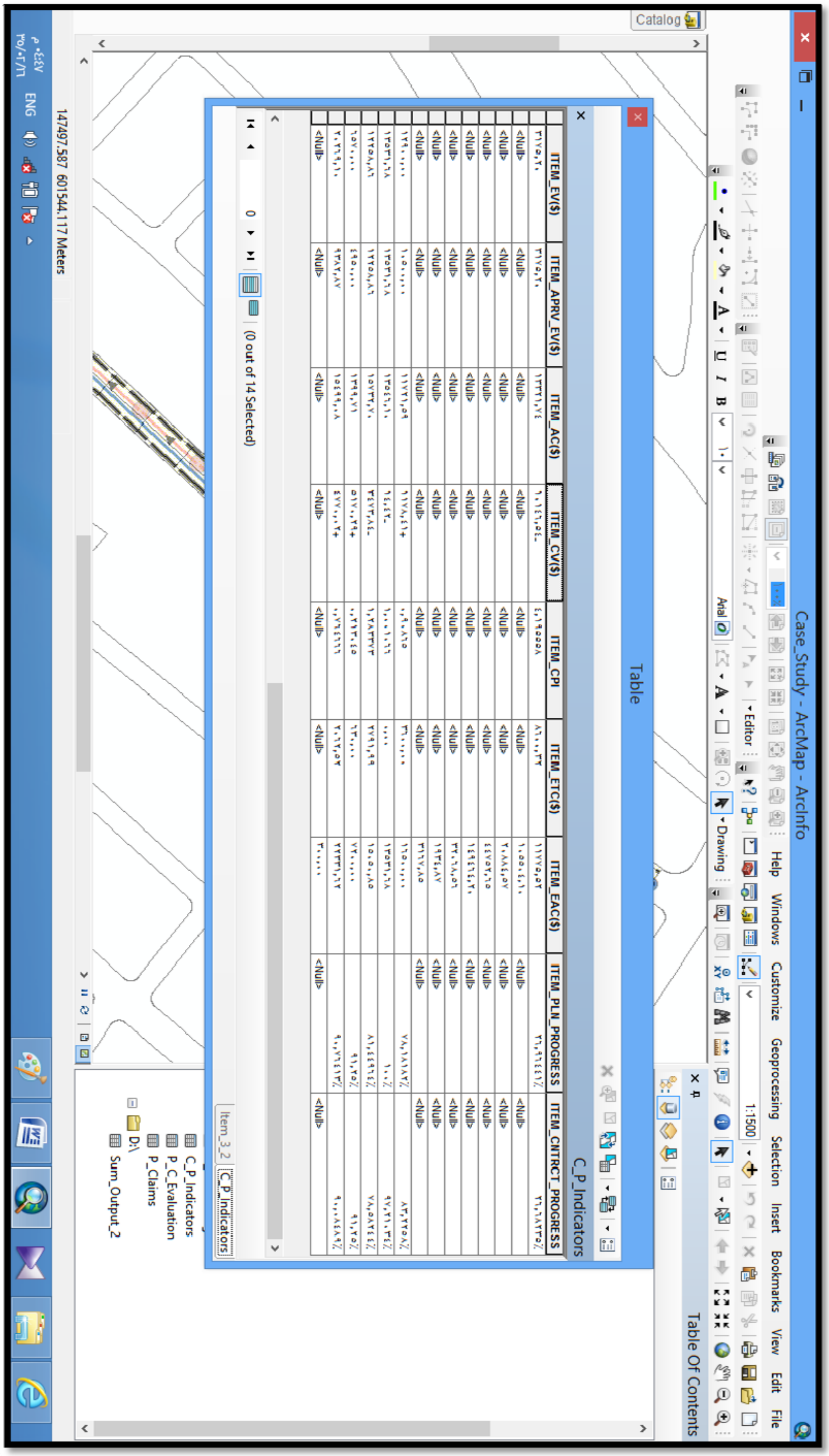

Figure 4-17 Cost Performance indicators values

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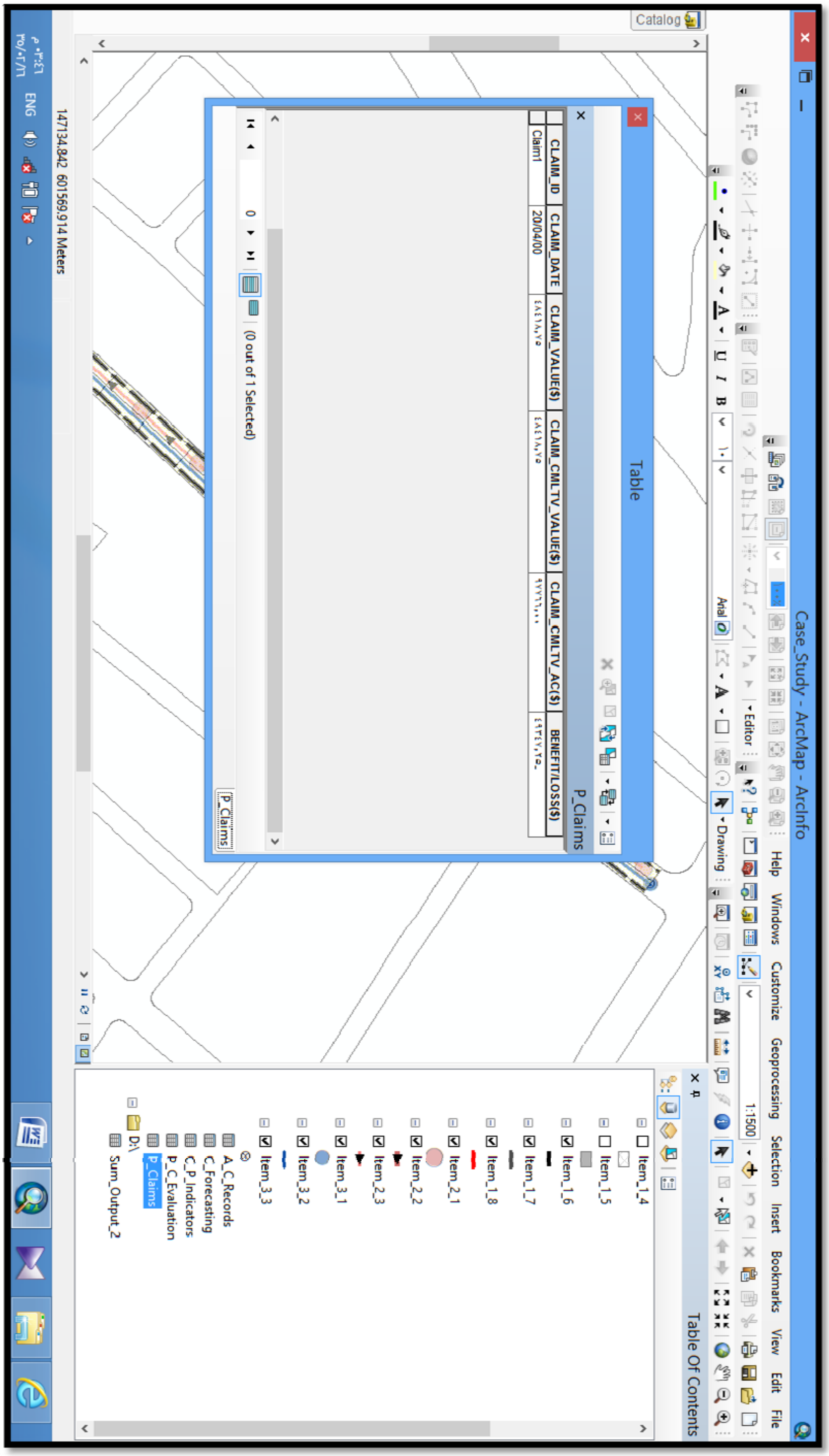

Figure 4-18 Project claims table

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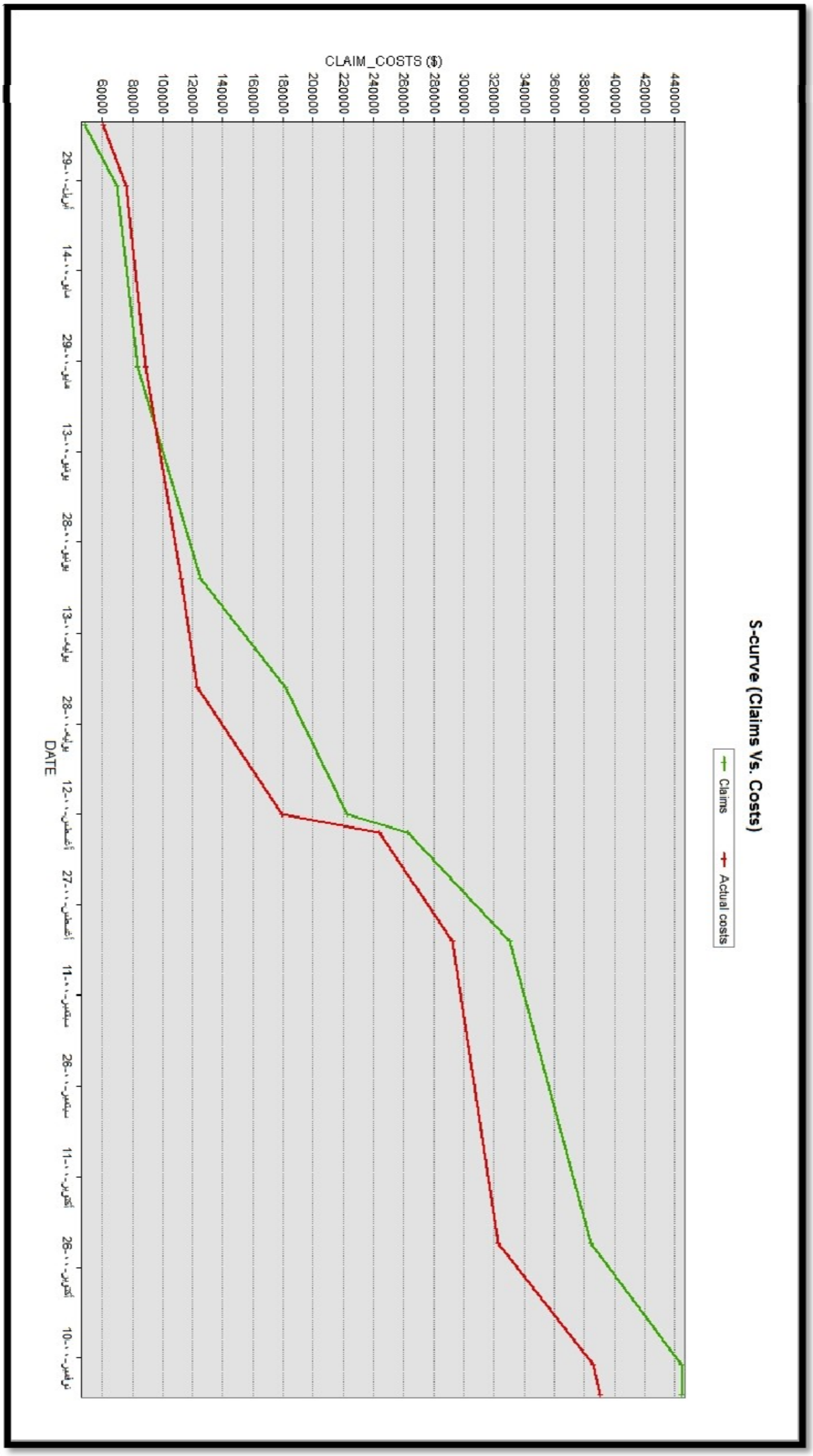

Figure 4-19 Claims vs. actual costs S-curves

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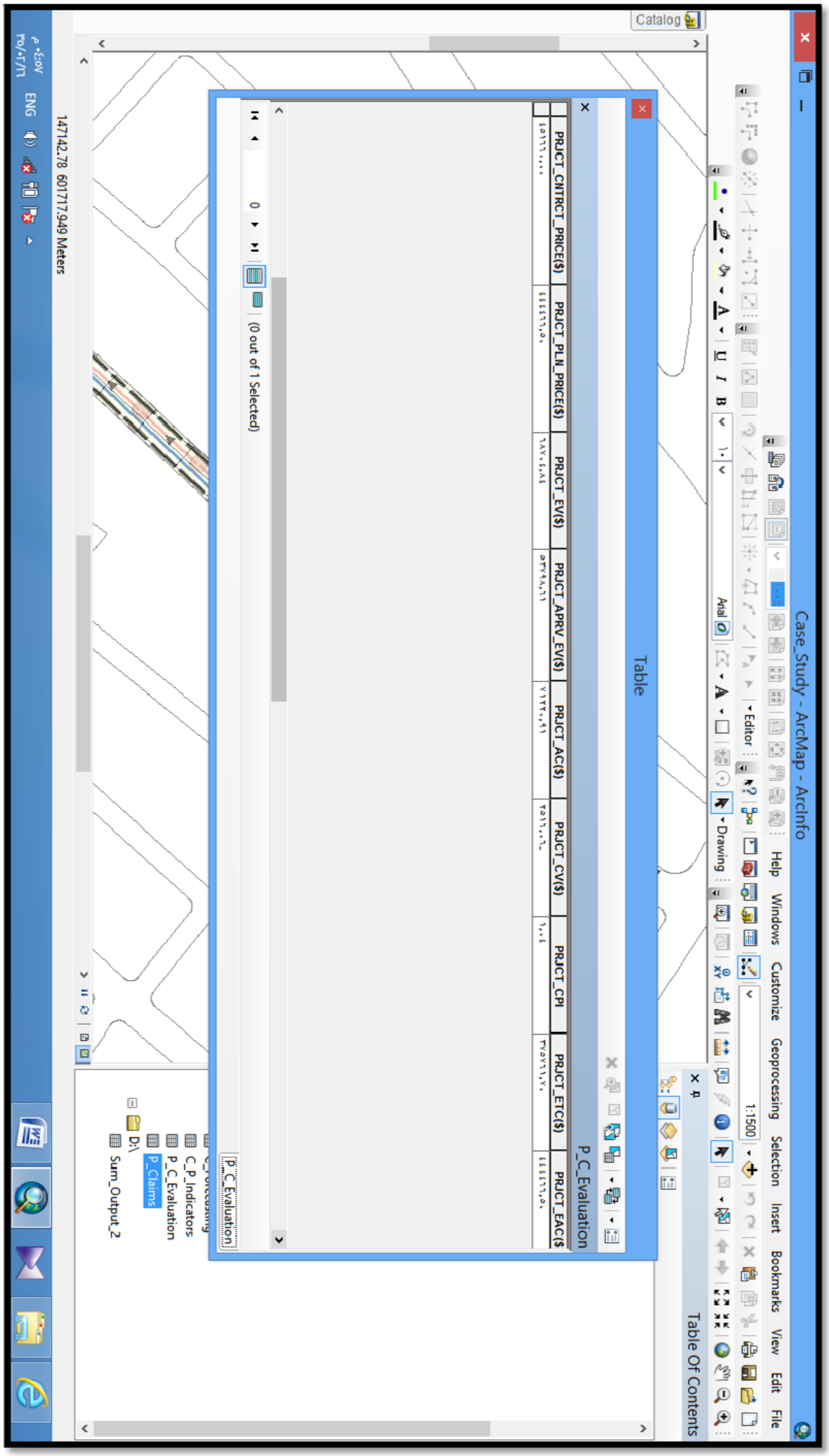

Figure 4-20 Cost control values for whole project

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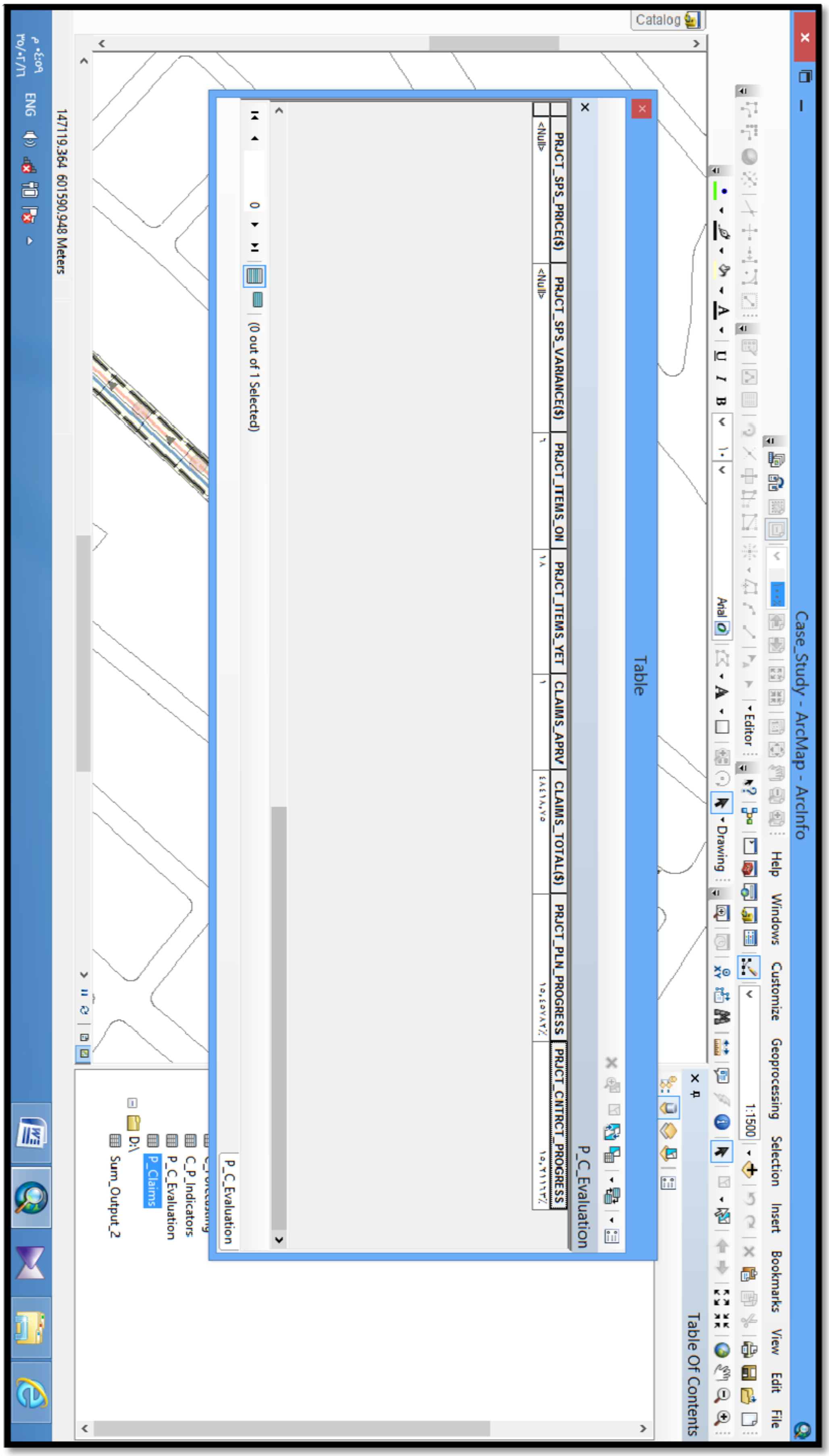

Figure 4-21 Summary for whole project

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Chapter Five

Conclusion & Recommendations

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5.1 Background

This research aims to improve cost control processes for infrastructure projects during cost evaluation phase; GIS capabilities have been utilized to achieve this aim.

About first objective, this research investigated the applying of cost control in infrastructures projects in local area and world, the big hole between these two environments was very clear; Unfortunately, local environment discard cost control concepts and concern only to final results without any methodology; On contrast with developed countries that pay attention and more care about this topic.

About second objective, this research considered that basic indicators of cost control are: cost variance (CV), cost performance index (CPI), estimation to complete (ETC), estimation at completion (EAC), forecasting variances and progress ratio. These indicators have to be focused at any cost control process along the project in order to track the project item by item.

About third objective, this research built a conceptual model that organize cost control processes, element (task) level was considered as data collection effort, Item level was considered as cost control base, and project level was considered as cost evaluation summary. Then, established computerized system that depend on GIS capabilities, where these capabilities can give integrated advantages for linking drawings with databases, another important advantage is performing accurate quantity survey for all elements in project by computerized method; Also, viewing final results that can be shown by tables or charts or graphical layouts.

5.2 Conclusion

General conclusion can be committed as:

1) This research focuses on cost control process during implementation phase of infrastructure projects in Gaza. There is a poor knowledge and poor applying of cost control process in the field.

2) The conceptual model deals with three levels of control. This dividing gives more control, and give more detailed information about each contractual items one by one, this approach is more scientific than tracking whole project with its end value only.

3) Unavailability of complete information of real infrastructure projects is an important obstacle for any case studies, poor documentation and more sensitivity about information security have to be treated by more awareness.

4) Unfortunately, most of CAD drawings in Gaza Strip are poor detailed, poor skills and more dependency of planers are major obstacle to introduce clear-

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detailed drawings. Preparing of CAD drawings to be compatible with GIS applications needs good skills at planning stage.

5) The computerized system based on GIS gives accurate quantity surveying and prices before project implementation; Also, cost forecasting is ready at once the initial quantity surveying performed. This enables user to understand the whole situation of project at early time, then decision making can be more effective.

6) Using of coordinate system within GIS environment give more advantage to system, it is very easy to use overlapping with so many feature classes or other data types that can describe the real situation of project site and surrounding areas; Also, using GPS can be more powerful to locate sites specially in large-scale projects or in rural areas projects.

7) Unavailability of approved Item coding make a problem of reconstruct feature classes every time by different Item IDs, this can make some confuse about comparisons between related items in several projects as a feedback.

5.3 Recommendations

General recommendations can be committed as:

1) Future researches can deal with cost control processes during previous stages (estimation and planning).

2) Future researches can deal with other points like claims and overhead expenditures more detailed.

3) Future researches can construct programmed user interfaces that can overcome many manual problems.

4) Future researches can deal with modelling volume and weight items to overcome manual calculation problems for "per-geometry quantity".

5) Future researches can deal with simple methods to use 3-dimention features that can give more accurate results.

6) It is very important to improve planning skills specially about preparing detailed CAD drawings to be more compatible with GIS applications.

7) Future researches can deal with statistical methods in order to check overall cost control processes, especially in Item level as main cost control level.

8) Future researches can deal with several baselines methods in order to document the project development steps.

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9) Future researches can deal with several currencies and its effects on cost/benefit values.

10) Future researches can deal with time schedules that can give more power to system; Time dimension is one of very factors that affect costs.

11) Future researches can deal with contractual item coding by standard IDs; this can be very helpful for programming of intelligent user interface.

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Appendix

Case Study Project BOQ

No.	Item	Unit	Quantity	Unit Price ($)	Item Price ($)
1	**Road Construction Works**				
1.1	Levelling of the existing road according to the design level (sub base layer) as shown in the drawings, work includes excavation and backfill with Kurkar material if it's needed that the compaction layer should be reached 98% of the bulk density, and the item includes the removal of obstacles such as concrete blocks, trees, fences, etc. out of the site as approval location by engineer or his representative.	M^2	11900	1.00	11900.00
1.2	Supply and spread a crushed debris material layer of 25 cm thick for the road by using the grader, and the item includes spraying water, compaction and all necessary works and compaction to density of 98% of the bulk density &CBR not less than 80% and the price includes all needed tests required by the specifications and instruction of engineer or his representative.	M^2	9000	12.00	108000.00
1.3	Ditto but the thickness is 10 cm for the sidewalk.	M^2	3000	7.00	21000.00
1.4	Supply and paving concrete blocks B400 (Interlock) of thickness of 6 cm and the face surface not less than 7 mm basalt layer, with hexahedral shape according to the engineer instructions for the for the sidewalk, and the work includes supply and spread a layer of clean sand thickness of 5 cm below the tiles with compaction, and the item includes making of the necessary tests before	M^2	3000	15.00	45000.00

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No.	Item	Unit	Quantity	Unit Price ($)	Item Price ($)
	supply according to technical specifications and instruction of engineer or his representative.				
1.5	Supply, spread and compact 6cm 3/4" asphalt concrete with percentage of bitumen not less than 5.2%, works includes (MC0) with average of 1.2 kg/m2 above the base course layers, painting for road of colours white / yellow, remove all defect material of asphalt and all required works to complete the job according to the tender documents and Engineer directions	M^2	9000	17.00	153000.00
1.6	Supply and construction of curb stone size (15×30×100) cm concrete B300 was cast automatically by a certified factory and compressed hydraulically for the sidewalks, and the item includes supply and cast of plain concrete B250 section 27 × 12 cm under curb stone and 22 × 12 cm curb stone back and the work includes filling of the blanks with concrete mortar and cleaning and treatment of water for 4 days, and the work includes supply and paint the stone a preparatory face and 2 layers with the required approved roads colour with glass powder, and the work includes supply and spread a crushed debris material layer of 15 cm thick at the bottom of the curb stone with a spray of water and compaction to density of 100% of bulk density (CBR of not less than 80%) and work includes the development of expansion joints every 12 meters filled with Kalkal and Mastic and all needed works to complete the job according to the specification and instruction of engineer.	M	1800	18.00	32400.00

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No.	Item	Unit	Quantity	Unit Price ($)	Item Price ($)
1.7	Supply and cast concrete B250 for Reinforced Concrete Beam size 15×30 cm with reinforcement 4 Φ 10, stirrups Φ6 @ 20cm and the price includes the work of formwork and excavation & backfilling and work includes the development of expansion joints every 3 meters filled with Kalkal and Mastic and all needed works to complete the job according to the specification and instruction of engineer or his representative	M^3	9	260.00	2340.00
1.8	Supply and install Steel Handrail Height 1.2m (vertical steel pipe dia. 3" and thick 3mm, horizontal steel pipe dia. 1.5" and thick 2mm) the work includes supply and cast concrete footing B250 & its size (35x25x25cm), fixed by two steel angle its length 30cm and size 30x30x3mm and painting (base coat and another two face painting) with all required works according to specification, drawings and instruction of engineer.	M	150	20.00	3000.00
2	**Sewage System Works**				
2.1	Supply and install circular manhole of 1.00 m diameter reinforced concrete class B300 sewage manholes as per specifications and drawings reinforced concrete slab, cast iron cover (25 tons capacity and 40cm opening and should be write SEWER/مجارى word in Arabic and English on cover); The item also includes excavation, supporting the trench sides and backfilling using clean sand with watering, and compaction after approval of the engineer.	No.	31	500	15500.00
2.2	Supply and install 250mm diameter UPVC pipes (SN8) with minimum wall	M	290	48.00	13920.00

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No.	Item	Unit	Quantity	Unit Price ($)	Item Price ($)
	thickness of 7.30mm and lay in all kinds of soil including excavation to the required depth, supporting the trench sides and backfilling with clean sand, and compaction the site. The price includes all necessary works, as specified in the specification, drawings and to the satisfaction of the Engineer.				
2.3	Ditto but 200mm diameter with minimum wall thickness of 5.90mm.	M	600	26.00	15600.00
3	**Water System Works**				
3.1	Supply and install circular manhole of 0.80 m diameter reinforced concrete class B300 water manholes as per specifications and drawings reinforced concrete slab, cast iron cover (25 tons capacity and 40cm opening and should be write WATER/مياه word in Arabic and English on cover); The item also includes excavation, supporting the trench sides and backfilling using clean sand with watering, and compaction after approval of the engineer.	No.	16	450.00	7200.00
3.2	Supply and install 110 mm diameter UPVC pipes with minimum wall thickness of 4.20mm 10 bar pressure including excavation to the required depth, supporting the trench sides and backfilling with clean sand, and compaction the site. The price includes all necessary fittings, as specified in the specification, drawings and to the satisfaction of the Engineer.	M	900	25.00	22500.00
3.3	Supply and install gate valve 110 mm diameter 16 bar pressure; The item also includes all parts as specified in the specification, drawings and to the satisfaction of the Engineer.	No.	2	150	300.00
	Summation				**451660.00**

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