Application of Visual Modelling Technique To The Sudan Investment GIS Model

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SUMMARY

On this paper visual modelling technique was introduced to generate a prototype GIS model for the investment projects in the Sudan. The modelling approach is implemented using the Unified Modelling Language (UML) as notation and the Unified Process (UP) of object-oriented software development as methodological process. The prototype model was developed the purpose of providing the correct answer for the question of "Where best to invest in what?"

By investigating the resulting prototype model, visual modelling approach has proved to be significantly functional for modelling GIS projects populated with large volumes of data, especially when characterized by data diversity and heterogeneity.

1. INTRODUCTION

The geographic information system (GIS) is evolving to a new big industry that serves many applications areas, which are considered vital to our daily life activities, such as water systems, electricity, transportation, and many other areas of countless applications.

All GIS applications should be quite understood and documented before rushing into any modelling process, as poor modelling will consequently convey wrong mapping of the applied system components. Poor models always indicate a waste of considerable amount of resources and time to be spent for a product with limited benefits to the users and far away from their initial requirements and expectations.

Visual modelling using formal graphical notations is believed to be a suitable solution for the proper modelling process that conceives the right mapping of any system reality through appropriate abstraction. This paper explores the possibilities and benefits gained from introducing and merging of visual modelling technique in the GIS, as applied to the investment potential in the Sudan.

The paper introduces the visual modelling technique to be considered as an additional modelling dimension that leads GIS developers to tackle problem stating, analyzing and solving of GIS modelling issues in more reliable and efficient way.

The visual modelling technique will guarantee proper development approach using the Unified Modelling Language (UML) which is considered as a general purpose, broadly applicable, tool-supported, and industry standardized visual modelling language for specifying, constructing, and documenting the artifacts of software-intensive systems.

2. VISUAL MODELLING REVIEW

In the last two decades visual modelling has evolved throughout several languages, most of them relying on the object-oriented paradigm as a base of development. Common examples of these languages are included in Coad and Yourdan (Coad, P. and E. Yourdon.,1991), Rumbaugh et al (Rumbaugh, J., M. Blaha, W. Premerlani, F. Eddy and W. Lorensen.,1991), Shaelr and Mellor (Shaelr, S and S. Mellor.,1991), Jacobson et al (Jacobson, I., M. Christerson, P. Jonsson and G. Overgaard. 1993), and Booch (Booch, G., 1994). In 1997 the Unified Modelling language was adopted as standard language for visual modelling to replace all these languages and to serve for any type of software development.
In the GIS context, and during the same above period, many researchers have conducted their researches using visual modelling but at the conceptual level only by focusing on the representation of the spatial component of the database using the entity relationship (ER) model or the object-oriented approach. The most important achievements in the literature using the entity relationship are:

- *MODUL-R (*Bédard, Y., C. Caron, Z. Maamar, B. Moulin and D. Vallière., 1996*).*
- *GeO2 (*David, B., L. Raynal, G. Schorter., 1993*).*

The second group using the object-orientation paradigm is:

- *GeoOOA (*Kösters, G., B.U. Page1 and H.W. Six., 1997*).*
- *Geo-OM (*Tryfona, N., D. Pfoser and T. Hadzilacos.,1997*).*
- *MADS (*Parent, C., S. Spaccapietra, E. Zimanyi, P. Donini, C. Plazanet and C. Vangenot.,1997*).*

Most of the above solutions have tried to express the issue of spatial component of the database modelling and to overcome the problem of applying non-spatial modelling language in the spatial database by extending existing languages and introducing new spatial types or classes in implicit or explicit way.

Another concern of these researches has been devoted to provide satisfactorily answers for topological aspects and spatio-temporal modelling of the data using the same techniques.
Among the different visualization modelling types, visual modelling is recognized as the abstraction and mapping of the real world process of any specific system to a graphical representation in order to develop object oriented software systems. Visual modelling comprises three main components known as the triangle of success (Terry, Q.,1998) as stated below:

- *Notation:* represents the language and communication diagrams usually used by the developers to represent their ideas and abstracted views of the system in concern and to provide the necessary semantics to capture the important artifacts of the system.
- *Process*: represents the methodology or the complete set of activities – and not their execution procedure- needed to transform the users' requirements into a consistent software system that satisfies these needs.

— *Tool*: represents the software to be used to implement the notation diagrams in order to produce robust and efficient solutions to the system modelling activity.

No significant attempts were done towards merging the visual modelling approach with geographic Information Systems and here we introduce it in order to investigate the potentials and limitations experienced during and after the merging process..

Geographic Information Systems (GIS) has become a widely applied technology due to the ever-increasing improvements and progress in both hardware and software incorporated with it, besides the successful projects it implements since its beginning. GIS has gained most of its value from the point of view of its ability to convey the geographic data from reality to the computer platform whether represented in object structure as vector data or in field structure in raster format.

With the increasing applications of GIS, more complexity and diversity in data types are introduced due to huge volume of data generally accompanied with the applications domains. This in turn has led to a growing interest in using different modelling technique to manage this data complexity.

ArcGIS software was selected to be used as a GIS tool for our purpose. The geodatabase of ArcGIS was implemented as an object-relational database management system, which serves as a generic data model for the sample data. The geodatabase supports both personal and multiple users' database. It uses ordinary Microsoft Jet Engines to store the data in Microsoft Access for small projects with limited data as in our case. The geodatabase stores data in feature datasets, which represents a container with known coordinate system and spatial extent. They haves both the spatial and non-spatial data stored as feature and object classes respectively, while relationship classes and geometric networks and planar topology represent the rest inside the datasets.

3. THE SUDAN INVESTMENT MODEL

The authors have developed a conceptual framework to represent the Sudan Investment Potential Model (IPM) as shown in Fig.(1). The UML model representation was reflected in Fig.(2) which consists of spatial and non-spatial entities in addition to the anticipated local and foreign investors who are expected to perform different scenarios to access and investigate the available investment possibilities.

The main path of the use-case scenario required by all investors is to answer the question of “"*Where best to invest in what?*”

The spatial entities at the national level are concerned with the items that depict different phenomena, facts or some sort of reality at that level such as climate, vegetation cover, transportation, etc.

The entities at state-level correspond to different sectors of investment such as agriculture, industry and services.

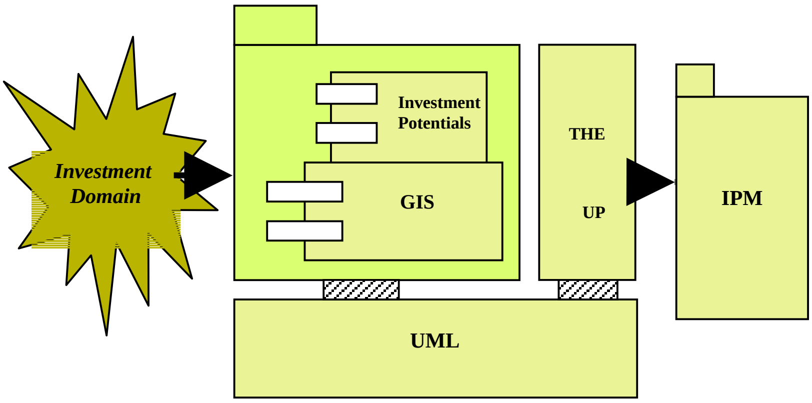

Fig. (1): Diagram of conceptual framework for IPM

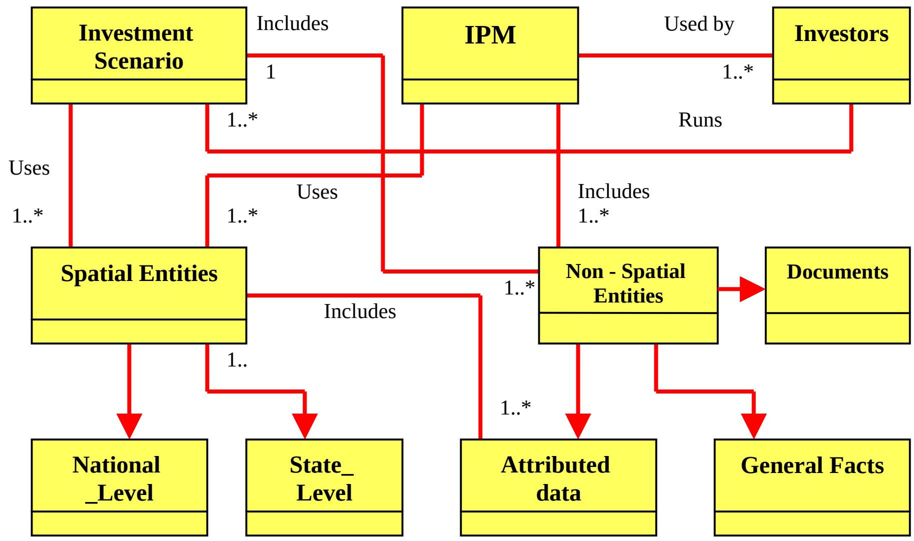

Fig. (2) : The layout of the conceptual framework

4. THE DEVELOPMENT APPRAOCH

To complete the tenets of the visual modelling i.e. notation, process and tool we have adopted the following approach:

- The Unified Modelling Language (UML) to be used as a notation.
- The Unified Process as a methodology process to conduct the development of the investment scenario.
- The Enterprise Architect CASE tool software from Sparx Systems to be used as a tool for the modelling.

The Unified process (UP) is considered as a software development process incorporated with a set of activities needed to transform user's requirements into a software system. The overall view of the process is illustrated in Fig.(3), it shows the software development life cycle expressed as phases on the horizontal scale while the workflow stages or disciplines are shown on the vertical scale.

The real unique aspects of the Unified Process are provided in three key phrases:

- Use-Case Driven.
- Architecture-Centric.
- Iterative and Incremental.

Scenarios are generally known as instants of use cases (Wieger, Karl.,1997), and it is the objective of this paper to implement the visual modelling technique by developing proper use cases using the UP as an implementation process to serve the modelling activity.

ArcObjects and Visual Basic for application (VBA) were used for the model customization and during the iterative design of the software components and artifacts.

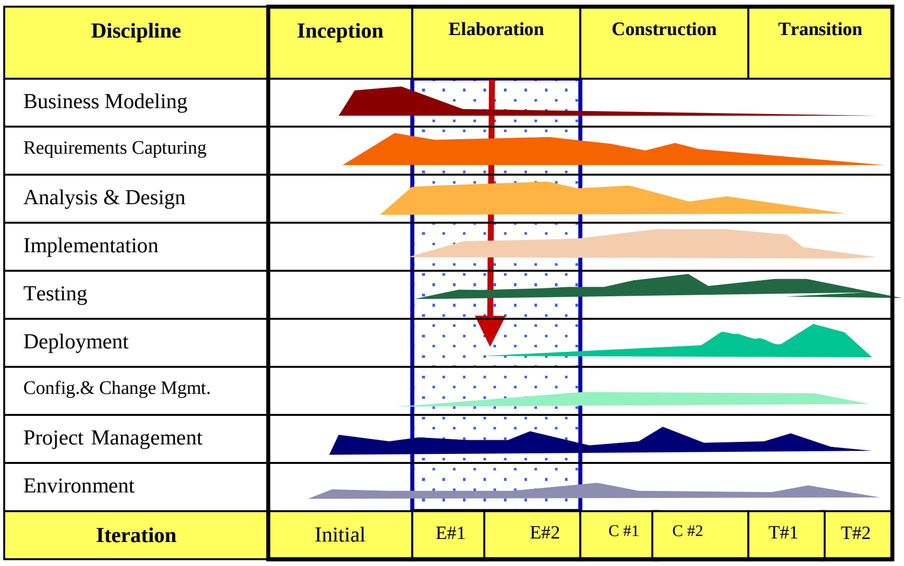

Fig. (3) : The overall view of the UP

5. THE INVESTMENT SCENARIO

The development of the investment scenario for the prototype GIS model of the investment in the Sudan was carried with a vision of providing investor with a GIS model supporting all investment promotion dimensions.
The model was developed throughout the following stages:

5.1 The Use-Case Model

This model represents a discrete set of activities performed by the investors (*actors*). It describes the different functional requirements needed by the new system.
The main use-case developed for the purpose of this paper provides the required functionality for the implementation of the investment scenario of “”Where best to invest in what?”. This approach gives the investor the proper guide to select the required investment activity in accordance to his interest.
The use-cases model contains the following requirements interacted by the investors as shown in Fig.(4):
Implement the Investment Scenario, (this represents the main path of the use-case).
Select the investment level, (represented by includes relation).
Select the investment sector, (represented by includes relation).
List the rest of scenarios, (represented by extends relation).

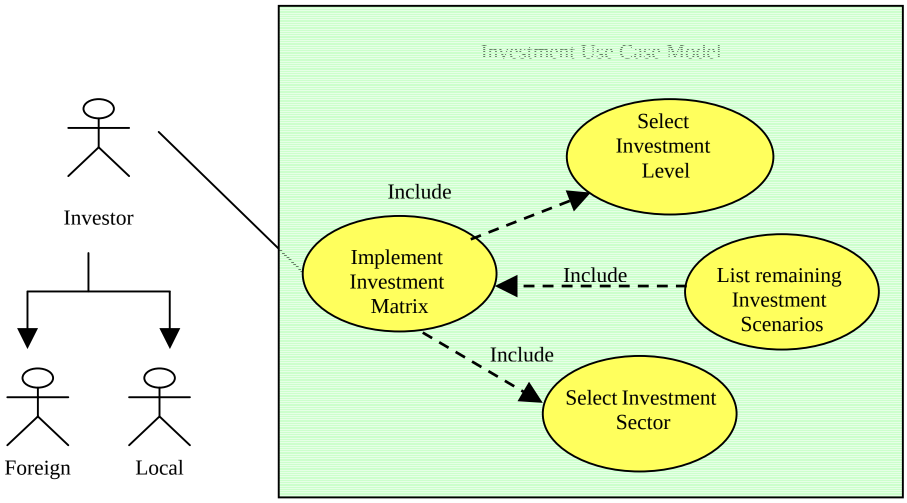

Fig. (4) : The use-case model

5.2 The Sequence Diagram

The sequence diagram in the UML is used to display the interaction between the actors, screens and object instances within the system. It provides a sequential map of the messages passing between objects over time.
The sequence diagram representation for the use-case model of the investment scenario is illustrated in Fig.(5).
Stereotyped icons are used for the representation of the implementation screen as boundary stereotype while the entity stereotype is used for the Investment Matrix.

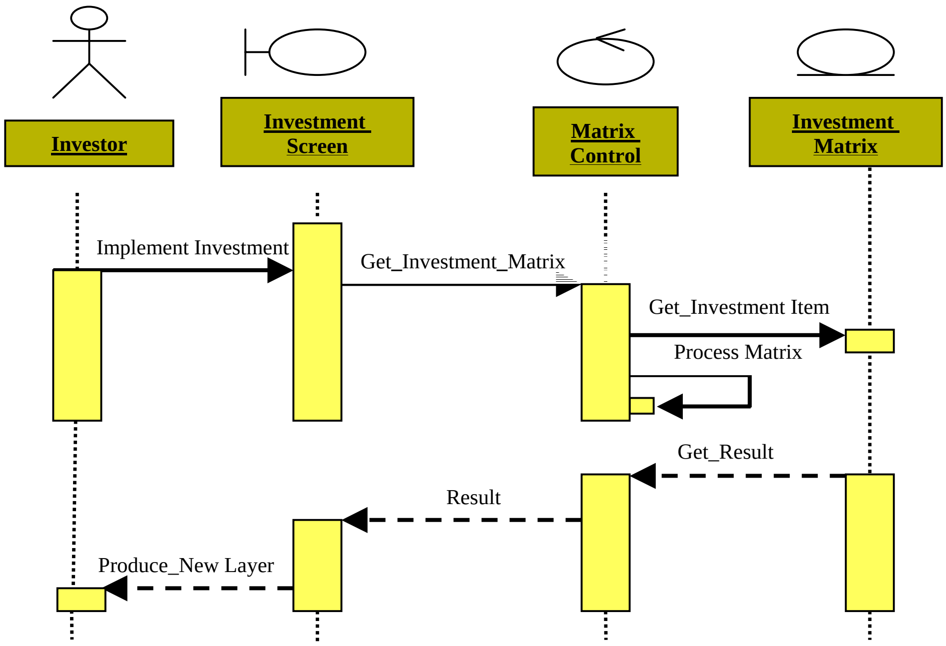

Fig. (5): The sequence diagram

5.3 The Investment Matrix

The Investment Matrix is a matrix proposed by the authors to be established for every expected investment item and to serve as a base for the analysis and decisions.
The Investment Matrix is constructed as follows:

- The items of the first column in the matrix express the expected investment activities for the selected sector and sub-sector.
- The items on the rest of the columns represent the necessary and optional requirements that are needed for the above investment item. Each one of these items should have a look-up table including further details.

5.4 The Model Outlook and Customization

The raw data for the above investment matrix is prepared in ArcView shapefiles then converted to the ArcGIS using ArcTool facilities. Component Object Models (COM) of ArcObjects is used within the Visual Basic for Application (VBA) Development Environment to perform the required customization.
The design aspects of the customization are directed towards leading the investors through simple access and versatile interaction with the model.

6. RESULTS AND DISCUSSION

The results obtained from the realization of the prototype model reflect the spatial extend of the possible investment opportunities that are available for the livestock products and related services.
Fig.(6) shows snapshot of the model during run-time illustrating one of the design UP iteration in VBA environment with a form including the selection screen for the investment matrix and the corresponding look-table needed for the analysis parameters.
Fig.'s (7, 8, and 9) depict the result of selecting the diary products as an example using the items of roads, population, temperature and power supply together with their look-up tables for analysis criteria.

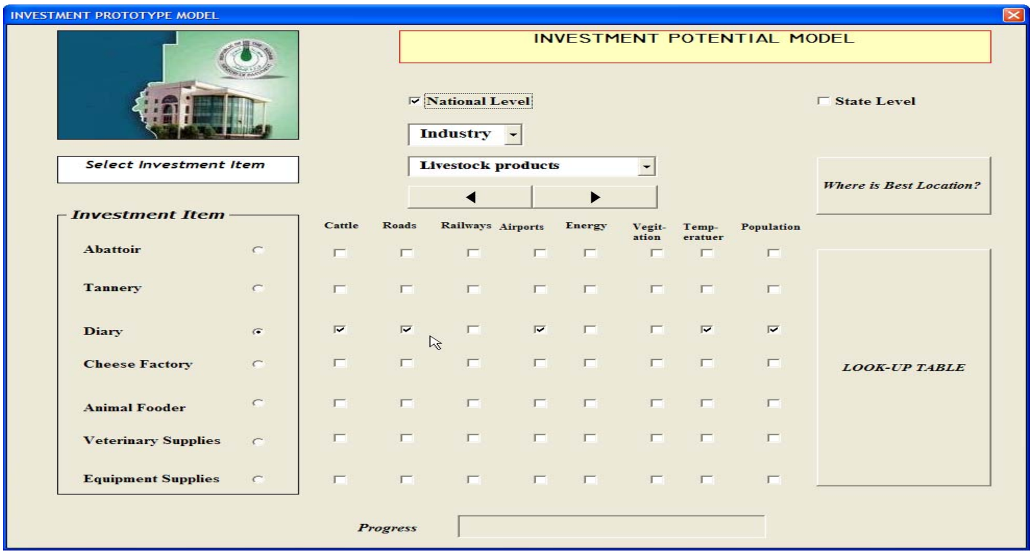

Fig. (6) : The prototype model during run-time

The following steps were applied in the iterative and incremental steps of the UP during development of the investment prototype model, which can serve as a guideline for the right steps to be followed for any similar model:

- Construction of the use-cases to gather the functional requirements by interviewing of the users, stakeholders and domain experts, after stating the vision and scope of the model to be developed.
- Documentation of the domain vocabulary and construction of the conceptual domain model that represents the model problem domain.
- Development and construction of the use cases that is further populated by the functional and non-functional requirements for the model.
- Preparation of the existing spatial data and production of the new data needed for the model.
- Selection of the database schema and populating the database with the appropriate data either directly or by exporting from the visual tool and then importing of the UML classes via eXtensible Markup Language (XML) data format.
- Analyzing of the data to be implemented for a prototype, to serve as test for only part of the whole model in order to secure time and effort at this stage before completing the whole model.
- Design the required functionality using the Activity and Sequence diagram to depict the dynamic behavior of the prototype model during run-time after deciding in regard to the software architecture and components.
- Developing of the required Graphic User Interfaces and users' views.
- Construction and creation of the metadata.
- Deciding upon the required hardware by constructing the appropriate input, processing and output device to be used in the implementation diagram.
- Deciding upon benchmarking and testing for the model quality.
- Deciding upon the data updating, general model life cycle and archiving process

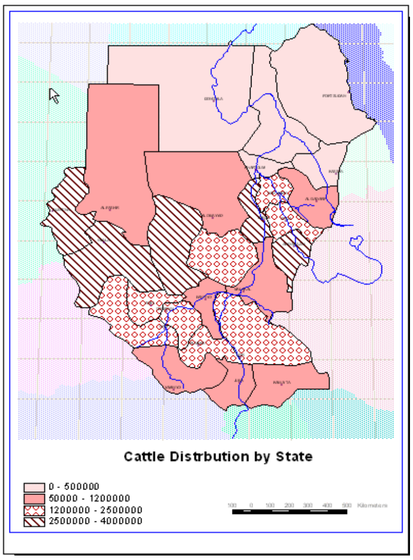

Fig. (7) : Cattle distribution by State

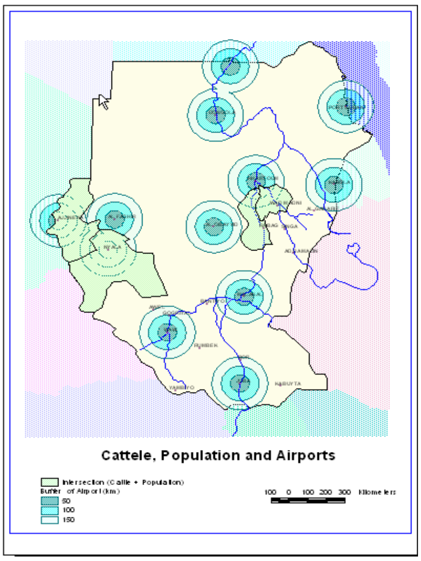

Fig. (8) : Cattle, population and airports

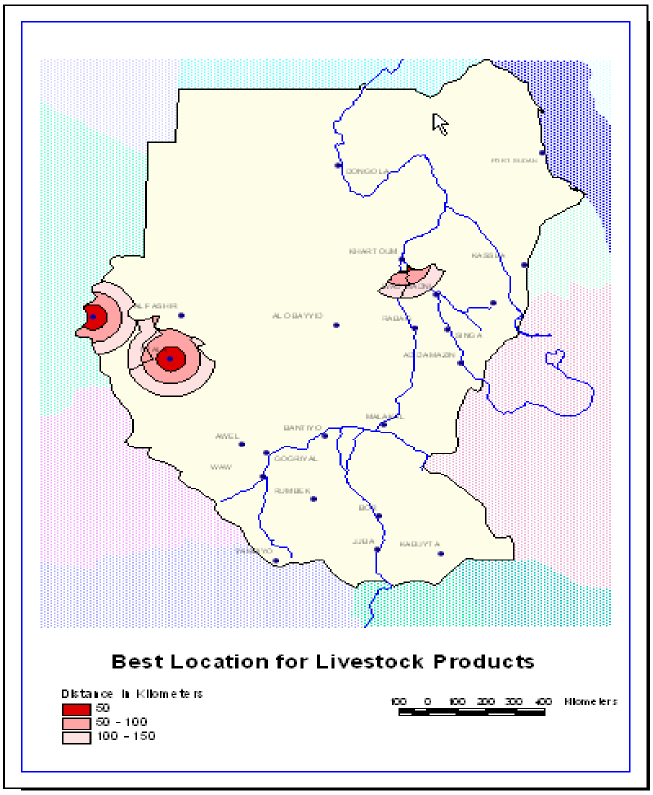

Fig. (9) : The best locations for investment in livestock product

7. CONCLUSIONS

This paper suggests that the Unified Modelling Language provides a potential benefit when used within the visual modelling software engineering concept to develop GIS models.
After investigating the consequences of possibilities gained from introducing the visual modelling approach to the proposed prototype model of the investment potential in the Sudan the following conclusions are reached:

- The Unified Modelling Language has proved to be a suitable graphical modelling language for the documentation and visualization of the different aspects of any GIS model, including the spatial data representation and the database schema.
- The Unified Process serves as a good guideline for the development of the GIS models as it leads the development process from the initial requirements of the users, through the other steps of analysis, design and implementation as derived by the actual use cases developed from the domain experts and users' knowledge expectations, which results in a realistic, useful and efficient model.

- For any GIS modelling activity, and especially when incorporated with data complexity, the visual modelling should be considered as a prerequisite for gaining of best abstraction results.
- The visual modelling approach has proved to be significantly useful for modelling GIS projects populated with large volumes of data, especially when characterized by data diversity and heterogeneity.
- The software engineering development concepts can be further extended to provide more efficiency in the GIS models customization by using of embedded or stand-alone object oriented programming, or by using of Component Object Model technology.

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