SELECTING A USABILITY EVALUATION USER GROUP – A CASE STUDY THE DEVELOPMENT OF A HYDRO-GIS TOOL AIMING URBAN FLOOD MITIGATION

RMM Pradeep,
Research Student (Department of Civil Engineering, University of Moratuwa)
(email: prathnayake@gmail.com)
NT Sohan Wijesekera,
Senior Professor (Department of Civil Engineering, University of Moratuwa)
(email: sohanw2@gmail.com)

Abstract: Flash floods which are becoming a common occurrence due to poor planning in the urban areas need user friendly tools for land managers to arrive at suitable alternatives. These tools require incorporating spatially distributed assessments performing several maps overlay and hydrologic computations for the evaluation of runoff generation before and after a proposed land development. The most common option for urban flood mitigation is the incorporation of land allotment based detention storages. The land managers need to capture the optimum sizes for these storages. A Hydro-GIS tool development was undertaken to ensure easy user friendly operation with automation of complex hydrologic and GIS computations. The tool with the objective of targeting non-technical users' demands high user friendliness and in order to achieve this, evaluations comparing usability becomes very important. Identification of the right number of users to evaluate usability is a requirement yet to be fulfilled. The present work successfully carried out a Hydro GIS tool development for the management of urban land development, achieving its functionality objectives while testing user friendliness with a user group of 23. Analysis shows that a group of over 13 users would arrive at an on average problem area identification rate of 90% or more.

Keywords: Optimum User Group, Usability Test, Hydro-GIS Tool Development, Urban Flash Flood, Detention Facility, Runoff Coefficient, Engineering, Information Systems

1. Introduction

Diversion of Stormwater from urban housing allotments directly to the road drains has been recognised as the major cause for urban flooding. Land allotment developments in the form of changes to slope, soil and land cover, lead to increase of surface runoff from such lands and therefore to prevent overloading of urban drains, it is necessary to incorporate a suitable assessment mechanism prior to granting of development approvals.

One methodology adapted by most developing nations is the state requirements to attach detention storages when executing land development projects (Parkinson & Mark, 2005). The reality is that the decision makers are often non-technical personnel thus making it difficult to make quick and joint evaluation with hydrologist / land managers and propose alternative solutions once a developer submits a project for approval. There are hydrologic tools to compute stormwater generation. However, available tools for land development assessments lack a combination of both GIS and hydrology embedded into a single system in a user-friendly manner. (Pradeep & Wijesekera, 2012). In order to support the majority of non-technical urban land managers, the present work carried out the development of a hydro-GIS tool for comparing stormwater generation before and after development and then to propose individual allotment based detention storage alternatives to mitigate adverse impacts. In the tool development life cycle, special efforts were taken to ensure a high usability through a careful evaluation.

2. Methodology

The tool development work was commenced with a comprehensive literature survey to capture the state of the art tools for land and stormwater management in urban area. The overall methodology of the case study is shown in the Figure 1. Literature revealed that the most influential land parameters for surface runoff generation are the slope, land cover and soil. Rational method and Unit hydrograph concepts were combined to capture the surface runoff hydrograph using a composite runoff coefficient for the land parcel seeking development approval. The tool was designed to demonstrate the change in the runoff coefficient after development and then to make provision for a detention pit at the downstream most point of the concerned land allotment.

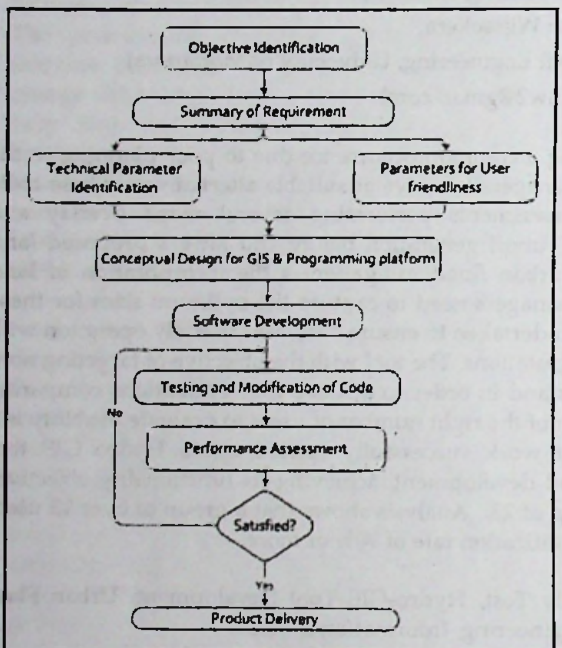

Figure 1: Overall Methodology

All stormwater generated from the land is first directed to the detention pit and the discharge from the detention pit is then transferred to the downstream drainages. A linear tank model of Sugawara concept with a single lateral outlet and a bottom outlet was assumed to represent the behaviour of stormwater through the detention pit. One of the major features in this tool is the capability to carry out on-screen map editing and attribute modification operations.

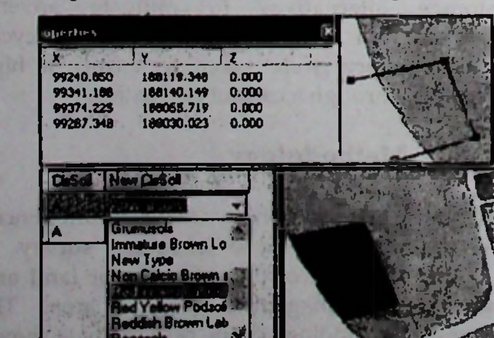

Figure 2: User interface to modify soil layer

A graphical user interface (GUI) combining the capability to change detention pit dimensions while experiencing the change in the pre and post stormwater hydrograph was included as part of the tool. A critical legal issue in the use of off the shelf desktop GIS tools is the data security that arises when making attempts to change decisions on land boundaries especially in urban areas where the demand is very high. In usual software, the basedata can be transported to another tool and then can be easily replaced without any feedback. In order to achieve security of dataset, the present work used an algorithm to capture any modifications which would be carried out external to the tool operations.

3. Development

Development of the tool (Pradeep & Wijesekara, 2012) identified three major tasks intended to be executed during the granting of land development approvals. The first task is to embed the land parcel modification facility with a user friendly GUI.. Intended land modification capabilities such as land acquisition and merging, soil, slope and land use changes were facilitated with the usage of online graphic tool operations and tabular data entry. Interface component to modify soil layer is shown in the Figure 2.

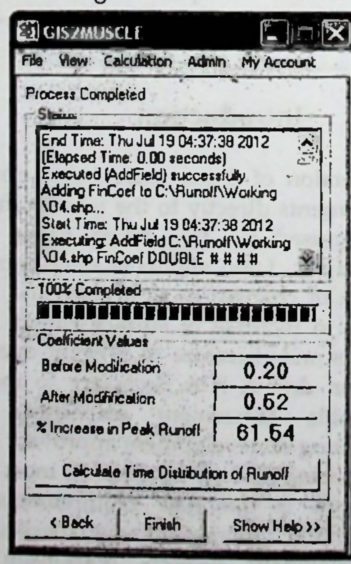

Figure 3: The Tool Enables Users to Compare Pre and Post Runoff Coefficients

In the second task the tool carryout spatial overlay of soil, slope and landcover to compute the area weighted average runoff coefficient for the entire land parcel. The composite runoff coefficient of the land allotment is then used to compute the peak flow using the rational formula and then to convert to curvilinear hydrographs. In this work the GUI enables a user to compare the composite runoff coefficients and then proceed to calculate the temporal distribution of runoff (Figure 3).

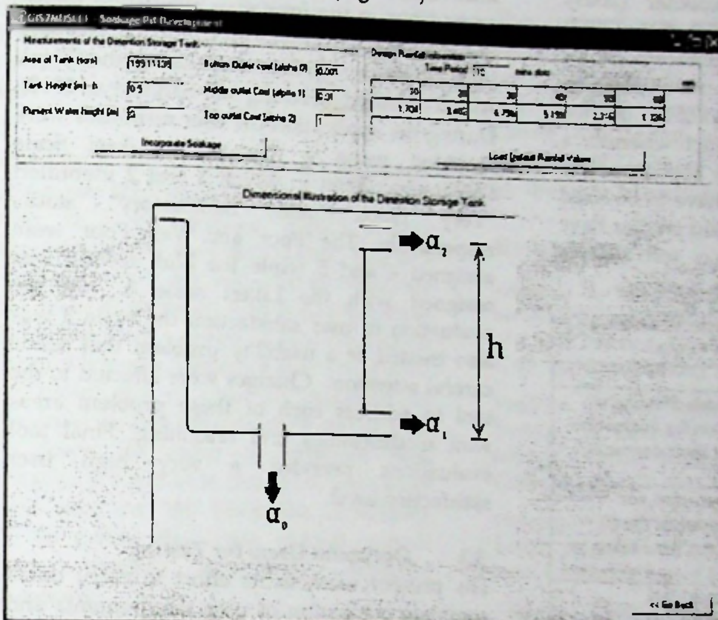

Figure 4: Dynamic Changing Capability of Detention Pit Dimensions

Determination of detention pit dimensions is facilitated through the GUI in Figure 4 which displays an illustration of the linear Tank Model concept of Sugawara (1995 and 1961) adapted for this work, Figure 5 shows the GUI for the comparison of outflow hydrographs subsequent to the incorporation of Detention pit dimensions and rainfall parameters. A concept of generating a security layer in the tool was incorporated to the tool development. Through an algorithm combining both spatial and non-spatial information of the land parcels, the security layer is generated and then a numeric code is computed for subsequent verifications. In this algorithm (Pradeep & Wijesekara, 2012), spatial extent and coordinates of the centroid are based on location information, while land assessment number and the associated road name are the non-spatial attributes.

3.1 Verification

The tool verifications were carried out to ascertain the fulfilment of user needs, user friendliness, accuracy of data capture & information delivery, flexibility of use , user confidence and ease of learning (Table 1).

Methods of user involvement (Azarian & Siadat, 2011) used in the tool development varied from user questionnaires to receive post testing feedback, one way and both ways interactive sessions with developer, guided verifications with an instruction guide, and manual step by step computations.

The Tool-User-Developer interaction is the most important aspect in the development of practical software especially in case of those which deal with dynamic, map based systems that require significant mathematical background computations. During the development phase, this was recognised at a very early stage. Faulkner (2003) has expressed that the mostly used 5-User concept would not be sufficient to fulfil the developer and user aspirations to develop a tool that can be put to good use.

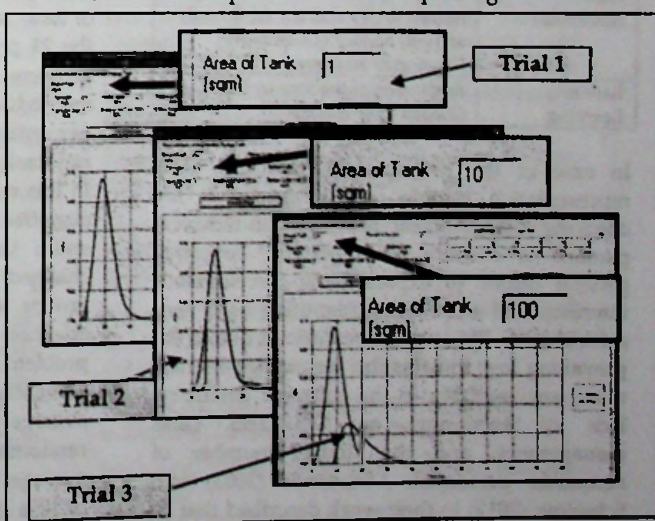

Figure 5: GUI for input of trial dimensions and comparison of outflow hydrographs

3.2 Users and Usability Testing

Determination of optimum number of users to assess the final product is an arguable task in the software usability assessment. For years, it was considered that five users are adequate for the assessment (Virzi (1992), Nielsen (2000)). Various research such as Faulkner (2003), Hwang & Salvendy (2010) and Schettow (2012) argued against the most embraced 5-user concept and expressed that this would be able to identify approximately 50-55% of the problems that exist in a product whereas, a group of 10 users would identify approximately 80-85% of the problems which have to be fixed to fulfil user aspirations. The said studies have expressed the need to have a test sample representative of the population.

TABLE 1: Verification Aspects and Methodology

Verifications	Methodology
User Requirements	Guided and Unguided testing of user-tool interaction for evaluation of aspirations and their degree of fulfilment
User friendliness	Ease of operation carried out through an evaluation of the (i) Number of clicks (ii) Time taken to function
Accuracy	Numerical and Graphical comparison of outputs with basedata, associated algorithms and conceptual models.
Flexibility	Evaluation of Tool functionality demonstrated during (i) Modifications (ii) Attribute changes (iii) Confirmations (iv) Dynamic nature and (iv) Output Generation
User confidence	User perspective assessment with respect to (i) Accuracy (ii) Security and (iii) Nature of Complete-Solution to an urgent need
Ease of Learning	Evaluation of the Step by Step Guided User Manual

In case of the present tool, selection of a representative sample out of specialists for checking the technical aspects, non-technical persons to identify administrative concerns, general public to express land development interests, and others was identified as a very difficult task. This was more difficult due to the prevailing low Information technology literacy rates, low maturity in the software industry, lack of awareness on GIS and Land management, and the limited number of accessible personnel. Faulkner (2003) and Schettow (2012) in their work described that 20 users would be able to identify 95% of the problem areas identified during evaluations. The present work which first commenced with the concept of a five user sample for tool evaluation, was later expanded to a group of 23 in order to evaluate the coverage and also to ensure the inclusion of a representative sample. Interaction with the 23 users could be grouped into 21 major problem areas that required interventions (Table 2). Usability test was carried out in the formative evaluation phase. In the test each user was given the tool to apply in a laboratory environment using the Think Aloud method (Hwang & Salvendy, 2010). During the application the user responses were recorded using a five point Likert Scale (Wikipedia, 2009) in which 1 and 2 identified "Very Good" and 'Satisfactory" status respectively. The "Poor" and "Very Poor" were assigned 4 and 5 while the Null feeling was assigned with the Likert scale 3. In the evaluation of user satisfaction the scale 3 was also treated as a usability problem that needs careful attention. Changes were affected to the tool to address each of these problem areas with modifications and reasoning. Final tool evaluations revealed a very high user satisfaction level.

3.3 Optimum Users for Testing

The present work in its effort to carry out a complete evaluation of user requirements and backed by the available literature, considered that a group of 23 users would be sufficient to highlight the majority of problem areas. Set of responses from the users were then subjected to an analysis to capture the identification capability when the size of the user group increased. Instead of addressing each question or issue raised by users, the analysis considered the 21 problem groups as the complete set of problem areas. An iterative computation methodology was used to capture the percentage of problem areas identified by a randomly selected user group of a given size. In this exercise all users taken for testing were classified in to one group representing the entire user population. Group sizes were changed from 1 to 20 insteps of one and the groups were selected using a random group selection in 100 trial selections to identify the problem areas picked up by each group and its percentage coverage. Figure 6 shows the average problem identification rate from a 100 random selections of each group. In Table 3 the average identification rate for the user sample of 10 is shown.

GIS2MUSCLE bundles the complicated GIS editing and overlay operations which are required to get a weighted averaged runoff coefficient enabling a non-technical person to successfully manipulate for solutions. It also includes intricate hydrologic computations, plotting of hydrographs and performing detention pit modelling to perform in a reliable manner thereby achieving easy operation. The quick and easy operation increases the value of this tool as a better watershed management tool.

The scientific study to compute the optimum user group size for tool evaluation revealed that a group of 5 on average, would enable detecting 64% of major problem areas. This is a higher number than that reported by Faulkner (2003), Hwang & Salvendy (2010) and Schettow (2012). In this work a group of 10 produced an average problem area identification rate of 87%. A User group size of over 13, produced an average problem area identification rate of over 90%. Since the rates of problem area identification arrived at in this work are values averaged over the 100 trials, the developers should be aware that only careful sample selections would lead to expected identifications.

As indicated previously, the sample selection for the tool evaluation required a significant effort due to difficulty in identifying a representative number of users having Hydrology, GIS, IT, Land Planning and Management experience. User responses to the problem areas reflect that the issues pertaining to GIS have been raised by only a few of the users while the most queried area is on how to use, how secure, how to print, legality and feedback. This also shows that tools of this type which use both maps and spatial attributes are still new to the industry and therefore the users are cautious when carrying out user acceptability testing.

5. Conclusions

1) A user friendly Dynamic GIS tool (GIS2MUSCLE) which enables on-screen modification of land allotment details and computing the runoff generation changes in order to propose a suitable detention storage for the particular allotment was developed.

2) This work identified that a user group of over 13 is required to arrive at an on average problem area identification rate of 90% or more.

3) The GIS2MUSCLE while incorporating a new concept to achieve security of basedata which are used for decision making, developed a well-researched GUI to achieve user satisfaction.

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TABLE 2: Major Problem Areas Recognised by the User Groups

#	Major Problem Areas Identified through User Interaction	Avg. Identification Rate (Group of 10)
1	On screen Map Interactions, Confirmation and Security Issues	4%
2	Capability to carryout Inter Layer Navigation	8%
3	Incorporating Map Zoom and Pan Tool usage when Editing	8%
4	Scale of Data Used and Adequacy	8%
5	Incorporation of Parent Software capabilities to customised GUI	8%
6	Incorporation of Permission Restrictions to Layer and Attribute Modifications	9%
7	Ambiguities in the Attribute Editing Options	9%
8	Compatibility, Portability and Tool Initiation Issues	12%
9	Sufficiency of Interactive Layer Capability	13%
10	User Centered Design issues, button and background colours, sizes, uniformity, appearance, impression and trend considerations	16%
11	Font Selection for Visual Clarity	16%
12	Adequacy of Attribute and Polygon Change Options for Information Updating	17%
13	Disparities in Expressed and Executed Functionalities	22%
14	User Centered Design issues, button and background colours, sizes, uniformity, appearance, impression and trend considerations	26%
15	Consistency Achievement at Out put comparisons	27%
16	Prioritisation of Screen Use for Graphics and Text, and Proportionate use of Screen and Issues	31%
17	User Assistance, Help and User Manual Requirements and Adequacy	36%
18	Tools for Printed Output Generation and Options	66%
19	Appropriateness of informative feedback	82%
20	Tools for Extracting mapped information and Printing Options	82%
21	Authenticity, Protection and Legality Issues during Implementation	88%
	Overall Problem Area Identification Rate	87%

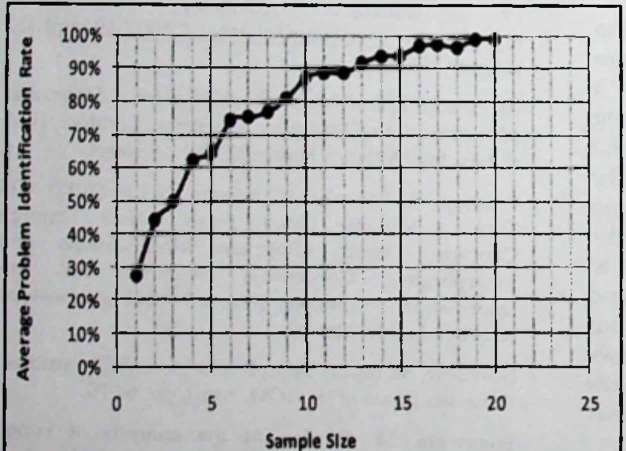

Figure 6: Variation of Average Problem Identification Rate with Sample Size

4. Results and Summary

The developed tool which was named as, Geographic Information System to Manage Urban Stormwater Considering Land Enhancement (GIS2MUSCLE), is an easy to use tool compatible with ArcGIS versions from 9.0 to 9.3. With its power to mitigate drainage issues though flexible alternative suggestions, this tool provides muscle to the urban planners and engineers. The tool development through its user interactive methods achieved the following as major objectives.

(i) Support to non-GIS users, (ii) Better error handling and accuracy in computations, (iii) On-screen operation capability, (iv) Continuity of operations for easy tracking of operational sequences and (v) result verifications.

To overcome the problem of incorporating security to an off the shelf general use GIS software, a security algorithm detecting a change to the last used data was successfully utilised (Pradeep & Wijesekera, 2012). This is one of the major features of this tool unlike in other cases, does not prevent editing land parcel data but recognises pilferage and warns the administrator though its capability to identify the version which was used at the previous occasion. Throughout the tool the what-if-analysis which provides the dynamic alternative evaluation capability, supports flexible decision making with changing situations. The capability to visualise changes to runoff coefficients enable modifying proposed land changes while the capability to visualise stormwater hydrographs provide options for detention pit selection. The