reviewed paper

Application of the Online WhatIf? Planning Support System in Peri-urban Spatial Planning; Case study of Muzaffargarh, Pakistan

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1 ABSTRACT

Out of South Asian countries, Pakistan is experiencing the fastest urbanization rate where more than half of the population will reside in urban areas after next seven years. Such a rapid transformation in urban areas calls for an extraordinary response from spatial planning agencies. Handling of complex urban phenomena with precision and time efficiency has created the dire need for shifting from manual planning processes to computer-assisted planning approaches. Although, previous studies on spatial planning practices in Pakistan have highlighted the stages and processes where adoption of planning support systems (PSS) can help improve the planning outcomes. However, the use of geospatial technologies and PSS have been quite limited in adoption and undertake by the planning profession.

With the advent of Smart Cities renewed awareness and support of data driven approach and tools such as PSS have assisted in bridging this utilization gap. To improve the adoption of PSS in spatial planning, many researchers have emphasized the need for research into understandintg and documenting real world use cases in ofg PSS supported planning. This research documents the case study of Muzaffargarh as the first spatial planning practice in the country's context where the Online WhatIf? PSS has been synchronized in the plan preparation process and used for the development of planning proposals. While documenting the details about the employment of OWI in the preparation of peri-urban structure plan (PUSP), it captures the processes, opportunities and challenges along with the user feedback. The country context specific procedural details covering the datasets, planning factors and assumptions have been comprehensively explained. It has been ensured that the details are sufficient enough to act as a guide for future plan preparation tasks of similar nature. Similarly, challenges and opportunities have been documented as part of the lessons learnt. This research concludes that the Online WhatIf? (OWI) has demonstrated to be a very good fit in PUSP preparation. This PSS has shown to provide a consistent and structured process to interactively explore, future land development options, which is considered a useful approach in PUSP preparation.

Keywords: Pakistan, Planning Support System, Peri-urban, Case Study, Smart City

2 INTRODUCTION

Globally, the phenomena of population growth has contributed to rapid urbanization at an immense scale and it is expected that the World will host 9.7 billion people by 2050 (United Nations, 2015). Since 2008, the number of people living in declared urban areas for the very first time in history exceeded the number living in rural localities (Angel & Sheppard, 2005; United Nations, 2014). This phenomena has affected Pakistan with relatively higher intensity where more than half of the population will reside in urban areas after next seven years (GOP, 2015; Jan, Iqbal, & Iftikharuddin, 2008). Such rapid urbanization calls for prompt and well thought actions by urban planners to manage spatial growth. In Pakistan, urban growth is managed by employing various forms of spatial plans. Peri-urban spatial plans (PUSPs) are one those instruments which are mostly prepared using conventional and manual methods (Anjum, 2008; The Urban Unit, 2009).

Throughout the plan making process in the PUSPs, the level of technological incorporation has been very limited (Afzal, 2016; Hussnain, 2013; Hussnain et al., 2017; Hussnain, Wakil, Waheed, & Tahir, 2016). However, recently, one of the plans (Muzaffargarh PUSP) has formally embedded a planning support system in its preparation exercise and witnesses improved work efficiency and enhanced quality. This research documents the case study of Muzaffargarh as a good practice in the country's context.

The Online What-If? Planning Support System (OWI) is an open-source, scenario based PSS deployed and managed by the Australian Urban Research Infrastructure Network (AURIN) (Pettit et al., 2015, 2013). OWI has been used and tested for various land use and scenario planning applications, as well as in its previous desktop version (Pettit, 2005; Pettit, Keysers, Bishop, & Klosterman, 2008; Pettit et al., 2015). As a measure to improve the adoption of PSS, Vonk & Geertman (2008) have emphasised the need for research and documentation of good practices of PSS supported planning (G. A. Vonk, 2006; G. Vonk & Geertman, 2008). More recently, Russo et al. (2018) identified issues of usability of PSS and provided recommendation to support further adoption which includes the education and training of urban planners in using PSS (Russo, Lanzilotti, Costabile, & Pettit, 2018).

While OWI provides detailed documentation on data preparation, suitability factors, weightings, suitability calculation, land use demand, and land-use allocations, the tool has its challenges. This research outlines the potential of OWI utilisation in peri-urban structure plan (PUSP) making by urban planners, while highlighting the opportunities and challenges faced during the OWI adoption in the spatial plan making process. Hence, this research documents the application of the Online What-If? PSS in the preparation of PUSP of a particular city in Punjab (Muzaffargarh).

3 CASE STUDY OF THE MUZAFFARGARH PERI-URBAN STRUCTURE PLAN

Muzaffargarh is district headquarter but a small city in the south-west of Punjab Province of Pakistan. It is located on the bank of Chanab river at 30°4′13″N and 71°11′36″E, covering an approximate area of 33 sq.km and housing approximately 250,000 people. The city has a gross density of 62 person/ acre with an annual population growth rate of 5.81 (Wakil, Hussnain, Yusuf, & Abdul Jabbar, 2016).

Muzaffargarh PUSP targets to provide spatial planning guidelines to manage urban growth in the peri-urban area of the city for the next 20 years, i.e. 2036. It has been prepared by a team representing the consortium of Sustainable Development Policy Institute (www.sdpi.org), City Pulse (Pvt) Ltd. (www.citypulse.com.pk) and National University of Sciences and Technology (NUST) with due involvement of TMA-Muzaffargarh and other relevant stakeholders (Wakil et al., 2016). The team comprised 11 town planners and 4 GIS experts. Most of the team members had no previous experience with OWI. Hence, skype based training (5 x 1-2hr tutorial sessions) were conducted by the AURIN team to skill up the plan makers. This PUSP is the very first and only project in Pakistan which has benefited from such planning centric geospatial technologies, in general, and the OWI PSS, in particular, during its preparation.

This case study focuses on the use of OWI for the land suitability and land-use allocation analysis stages. Figure 1 explains the flow of steps required to achieve this task including data preparation, project setup, and demand setup, allocation setup, developing suitability maps and developing allocation maps.

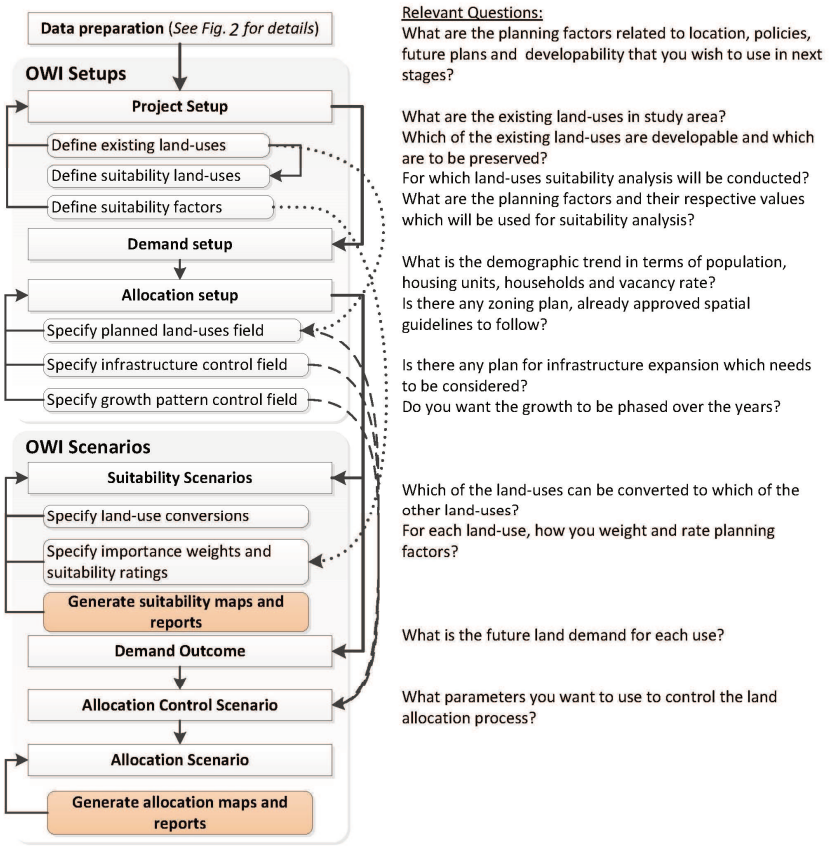

Figure 1: Procedure for land suitability and land-use allocation analysis with OWI

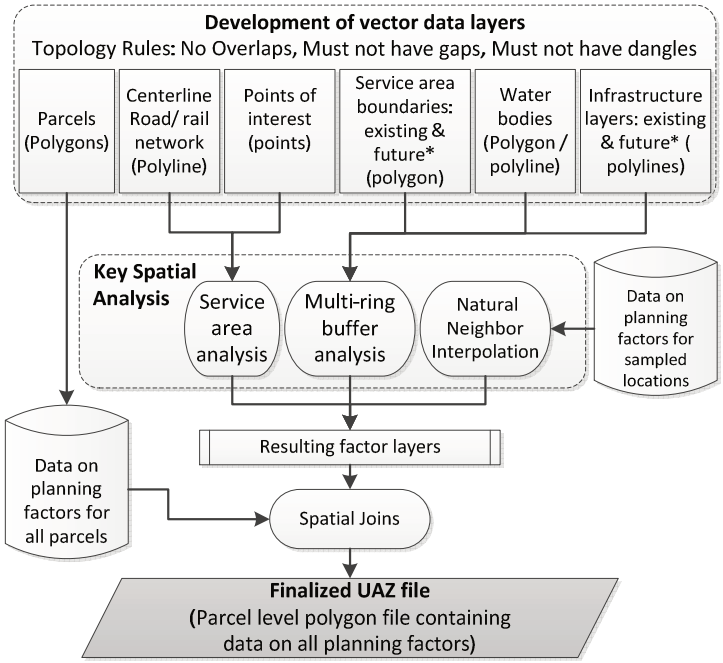

Figure 2: Data preparation and creation of UAZ file for Muzaffargarh PUSP

3.1 Data preparation

Data preparation for OWI is one of the most important but relatively less documented stages. This stage requires comprehensive and relatively tedious processes of preparing data for each and every parcel about all the factors which will be used during plan making at later stages. Since OWI requires a single UAZ (uniform

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analysis zones) of the study area (a shapefile containing a polygonal layer of parcels filled with attribute data) as input; all of the data preparation happens before setting up an OWI project.

Figure 2 explains the process adopted to create the underpinning UAZ file for OWI during Muzaffargarh PUSP preparation. First of all, vector layers have been developed using heads-up digitization on high-resolution satellite imagery. These layers included the building and land parcels, center line roads and rail network, water bodies and POIs. Furthermore, layers representing service areas (water supply, sewerage, solid waste collection etc) and infrastructure lines (high tension electricity, gas etc) have also been created showing the current coverage and the future plans. It has been ensured that all the layers comply with the topological rules; "No Overlaps" and "Must not have gaps"(though this is not a requirement in OWI) for polygonal layers and "Must not have dangles" for polyline layers.

At a second stage, depending upon their nature, these layers have gone through service area analysis, multi-ring buffer analysis or/and neighborhood interpolation analysis. Later on, the resultant attributes (planning factors) have been attached to each parcel through location-based queries and spatial joins. Finally, after removing slivers and muti-part features, the UAZ shapefile has been finalized.

In the case of Muzaffargarh PUSP, the final UAZ contains 52,000 parcels representing parcels of land and data on the following factors/variables has been developed and associated with each parcel in UAZ:

Sr. No.	Factor Category	Indicator	Definition / Classification	Prepared / collected by	Usage in OWI
1	Development potential	Land-use	All land uses	Field survey	Defining existing land-uses and suitability land-uses
2	Development potential	Land Value (per marla)	Equal intervals from 100000 to 1000000	Field survey	Defining suitability
3	Composite	Age and condition of building	Range of 1-10 scale	Field survey	Defining suitability
4	Future Plans	Accessibility through future roads	Yes No	Future plan of P&D department and TMA	Growth pattern control
5	Future Plans	Future area for municipal services	Yes No	Future plan of P&D department and TMA	Growth pattern control
6	Development potential	Growth trend	Rapid Slow No growth	Field survey, historic image analysis	Growth pattern control
7	Policy	Declared commercial	Yes No	Declared commercial roads under Commercialization policy	Scenario making
8	Policy	Agriculture productivity	Range of 1-10 scale	High-value agriculture land from Revenue department	Scenario making
9	Locational	Flood Prone Area	High Risk, Medium Risk, Low Risk	Field survey, flood zoning map	Defining suitability factors
10	Locational	Adjacent to primary roads	Yes No	Buffer analysis	As above
11	Locational	Distance from built-up area	< 0.5 km, 0.5 - 3 km 3 - 5 km	Multiple ring buffer analysis	As above
12	Locational	Distance from Residential Area	< 1 km, 1 - 3 km, > 3 km	Multiple ring buffer analysis	As above
13	Locational	Distance from bus terminal	>5 km, 3 - 5 km, < 3 km	Service area analysis	As above
14	Locational	Distance from Railway Station	< 3 km, 3 - 5 km, > 5 km	Service area analysis	As above
15	Locational	Distance from canals	Equal intervals from 100 m to 1000 m	Multiple ring buffer analysis	As above
16	Locational	Distance from higher order education facilities	< 1 km, 1 - 3 km, > 3 km	Service area analysis	As above
17	Locational	Distance from higher order health facilities	< 1 km, 1 - 3 km, > 3 km	Service area analysis	As above
18	Locational	Distance from higher order employment centers	< 1 km, 1 - 3 km, > 3 km	Service area analysis	As above
19	Locational	Distance from Industry	< 1 km, 1 - 3 km, > 3 km	Service area analysis	As above
20	Locational	Distance from Landfill Sites	< 0.5 m, 0.5 - 1 km, > 1 km	Service area analysis	As above
21	Locational	Distance from Primary Roads	< 0.5 m, 0.5 - 2 km, > 2 km	Multiple ring buffer analysis	As above
22	Locational	Distance from Sewerage Pipes	< 0.5 m, 0.5 - 2 km, > 2 km	Multiple ring buffer analysis	As above
23	Locational	Distance from Overhead Public water tanks	< 0.5 m, 0.5 - 2 km, > 2 km	Service area analysis	As above

Table 1. Planning factors associated with each parcel in UAZ

3.2 Project Setup

OWI project setup is required to create a new project in OWI where the user is allowed to specify UAZ data fields, define existing land uses, define suitability land uses and define suitability factors.

Specifying the 'developability' of a land-use is a very important consideration at this stage, as it describes which of the land-uses (i.e. land parcels carrying that land-use) should be considered developable. In the case of Muzaffargarh PUSP, the following assumptions have been considered:

- All land uses falling under existing built-up areas are 'not developable. Non-developable parcels of land are forced to remain as they are throughout the whole modeling exercise in What-If (i.e. it is a restriction imposed on the allocation algorithm, regardless of the suitability index).
- Within the existing built-up area, parcels containing vacant land and agriculture land of low productivity are 'developable'
- All land parcels falling under peri-urban area are 'developable', except agriculture land of high productivity, orchards, nurseries and fruit forms, graveyards, waterbodies, right-of-way of primary roads, religious buildings (mosques, shrines etc).

As a next stage residential, commercial, industrial, public and parks open spaces have been declared as the land-uses for which suitability maps will be generated. Later on, planning factors have been specified and their values have been initialised. The list of planning factors is given in Table 1. See Figure 3 and Figure 4.

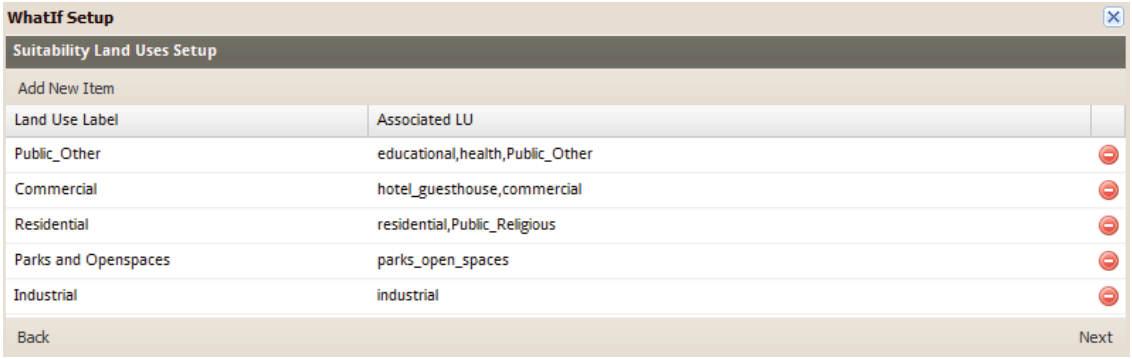

Figure 3: OWI screenshot reflecting land-use for which suitability scenario will be generated

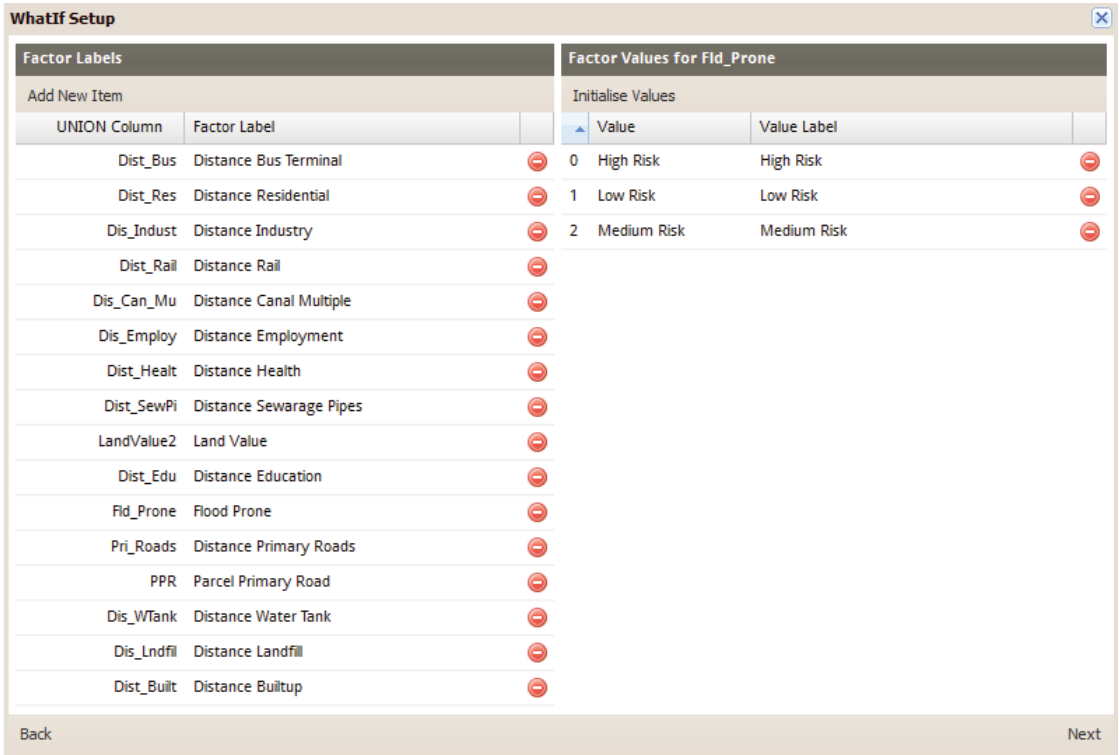

Figure 4: Interface for specifying planning factors and factor values

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3.3 Demand setup

The calculations of future land requirement according to residential and employment land demand is done through Demand Setup. For Muzaffargarh, the data collected from primary surveys has been used to input the current statistics for population, household, housing units, employment etc. Values for two previous years 2006 and 2011 have been calculated using the exponential growth formula based on the results of 1998 Census report. 2036 was specified as the Projection year.

3.4 Allocation setup

Allocation setup allows the user to specify the land allocation for projected land demand from three perspectives including specification of already planned land-uses, infrastructure control and growth pattern.

In the case of Muzaffargh, the previous outline development plan expired in 1997 and there is no applicable zoning plan which could be used to define planned land-uses. However, some approved housing schemes and projects including Allama Iqbal town, Tayyip Erodgan Housing complex and some designated parks were specified in planned land-use field. For infrastructure control, I&S department was consulted while the growth pattern was derived from discussions with the urban planning department of TMA.

3.5 Suitability scenario

The Suitability scenario setup permits the user to specify land use conversions, define importance weights and suitability ratings for the planning factors already enlisted during the project setup, compute suitability scores, and finally view suitability maps and reports.

It is important to mention that only the land uses which are marked ‘developable’ during project setup are allowed to specify land-use conversion. In the case of Muzaffargarh, all of the developable land-uses were checked for conversion into the suitability land-uses. At the next stage, planning factors were then assigned relative weights according to their association with different land uses. Weight assignment was a subjective process which was based on the opinion of urban planners and government officials.

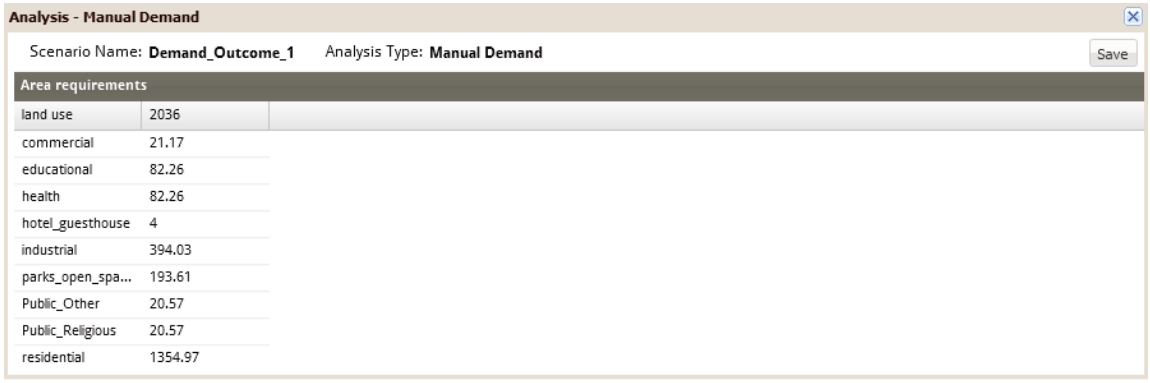
3.6 Demand scenario

The demand scenario function of OWI allows the users to calculate or specify future demand for land. Such demand can either be generated using projections on population and employment growth assumptions or it can be specified manually for various land-uses. The former process is relatively more data hungry, especially as data related to employment-related land demand is not available at a fine grain scale. Hence, for Muzaffargarh, future land requirements for each land-use were derived from the National Reference Manual (NRM) using projected population for the year 2036, see Fig 5.

3.7 Allocation scenario

This is the final setup which helps the user in allocating the projected land use demands specified in Demand Scenario to different locations on the basis of their relative suitability, as defined in the Suitability Scenario, and the allocation controls defined in an Allocation Control Scenario.

For the allocation setup, the suitability scenario, demand outcome, and allocation control scenario have been used. The land-use order was defined as per the requirement of our study area.



land use	2036
commercial	21.17
educational	82.26
health	82.26
hotel_guesthouse	4
industrial	394.03
parks_open_spa...	193.61
Public_Other	20.57
Public_Religious	20.57
residential	1354.97

Figure 5: Future demand for land-uses generated using NRM and provided to OWI using Manual Demand specification

4 RESULTS AND DISCUSSIONS

In the Muzaffargarh PUSP case study, OWI has helped in generating parcel-level land suitability maps for five different land uses. Once the suitability scores are calculated, suitability maps can be viewed for any selected land-use. Figure 6 shows the suitability maps for commercial and industrial land-uses in Muzaffargarh.

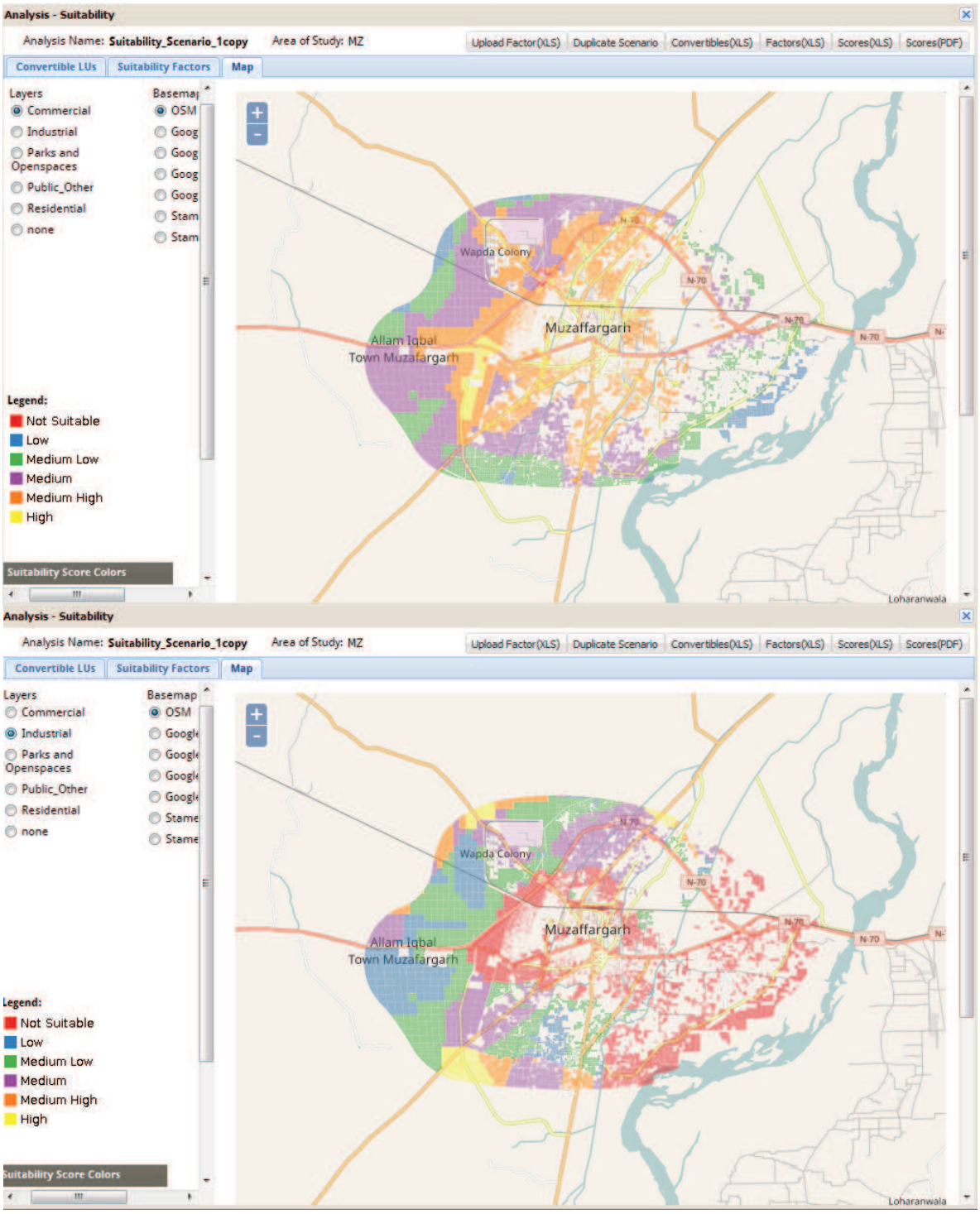


Figure 6: Suitability maps for commercial and industrial land-uses (top to bottom) display in OWI

The allocation module of OWI helped in translating policies (preserving agriculture and forest land, avoid development in flood prone area etc) and public priorities into a spatial plan. Figure 7 illustrates the land use allocation for each parcel of Muzaffargarh. Final resulting maps were used to formulate the zoning plan of the city.

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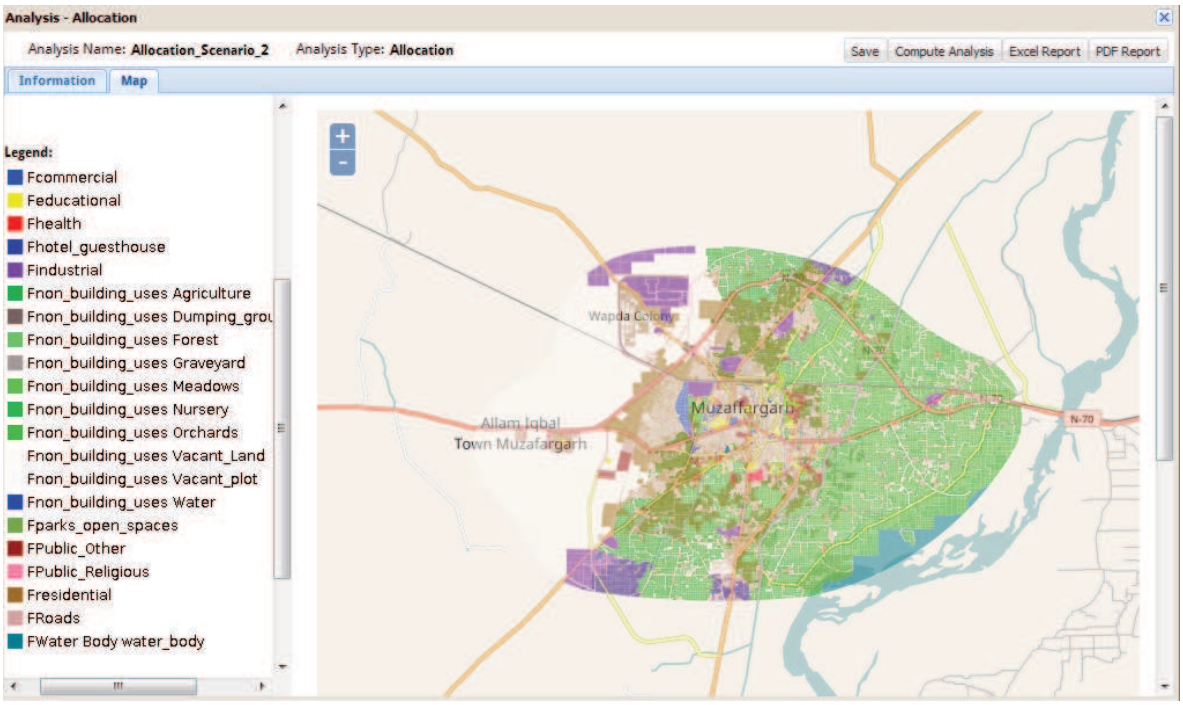

Figure 7: Screenshot depicting the parcel level land-use allocation for Muzaffargarh, displayed in OWI

4.1 User Feedback

Almost all of the team members involved in the Muzaffargarh PUSP has shown a higher level of satisfaction with the OWI as it provides effective tools to support analytical planning tasks which have been suffering from extremely low GIS utilization earlier. Furthermore, OWI overcomes the common demand and supply-side limitations related to PSS output quality, user friendliness and disintegration of tools by offering planners a set of powerful functions for generating land-use suitability and land-use allocation scenarios under any given set of conditions/ assumption. While doing so, it has allowed the team focus on planning side without worrying about the GIS related background processes.

The ability to generate scenarios, change planning factors and observe the impacts of those changes on city spatial form has enhanced planners' abilities to comprehend the impact of various suitability factors and decide upon a preferred option of growth. Many of them excitedly narrated that it was the first time, they were able to see the impact of their decisions on city's future at a longer time horizon.

5 LESSONS LEARNT FROM THE CASE STUDY

During this undertaking to match and fit OWI into peri-urban structure plan preparation in the Pakistani context, the following lessons have been deduced against each stage of the implementation process:

5.1 Project initiation

- OWI follows a bottom-up approach (AURIN, 2016) and this PSS requires significant data inputs. Since most of the plan preparation exercises start with data collection, careful considerations must be taken for the selection of indicators and design of a robust data structure that can meet OWI data needs.
- The plan making team (particularly urban planners and GIS experts) must be thoroughly capacitated about the OWI workflow for coordinated synergies.

5.2 Data preparation

- Land Suitability factors and their respective range of values that will impact on land use development must be listed carefully and in agreement with the plan making team, especially urban planners and GIS experts
- It is useful to list planning factors under following categories:
    - Proximity factors: reflecting proximity to or distance from relevant urban infrastructures

  - Future plans factors: containing information about the approved future plans of stakeholder departments, particularly the future plans for infrastructure and municipal services expansion
  - Policy factors: representing policy choices that can be used in scenario development at later stages
  - Environmental conservation vision will require planning factors to include environmentally sensitive areas, while economic growth vision might lead to the inclusion of factors associated with income generation potential of sites and land uses
  - Developability (Development potential) factors; covering the characteristics affecting developability of a parcel in positive or negative ways, e.g land price, existing land use, height of building, condition of building, infrastructure suitability for higher density
  - Composite factors; representing a composite of two or more factors. For example age of building and condition of building may come under the category of developability factors, but they can be combined into one Composite factor, to reduce the number of factors being considered in OWI.

- Future plans of TMA's infrastructure and services department (I&S), as well as other civic departments regarding the expansion of infrastructure (particularly roads and civic facilities) must be captured at this stage and be made part of UAZ
- It must be ensured that each parcel in UAZ contains information on all planning factors which will be used later in OWI processing. Currently, the application doesn't support the addition of any missing factor at a later stage, representing a limitation of the tool. In this case, the new data needs to be merged into the UAZ data input and a project needs to be re-created in the OWI for that to take effect. The re-creation of the project can be time-consuming.

5.3 Project setup

- Considering Landuse Rules 2009, dividing parcels into an established built up area and the peri-urban area is a good option. It allows more control in specifying what land use should be set to be developable or not.
- In order to ensure infill development, vacant land and agriculture land of low productivity falling with established built up area should be set as 'developable'.
- In case of a peri-urban areas areas of high environmental, cultural, religious, security sensitivity can be set to be 'not developable'.
- It must be understood that the suitability land-uses are primarily used to identify suitable areas for higher order facilities. Basic level facilities like mohalla mosques, primary schools, basic health units, daily shopping centres, etc are considered a part of the residential area. Since the area demarcated for the residential purpose will be developed under Housing Schemes & Land Sub-Division rules, all these lower order facilities will be covered automatically.

5.4 Allocation setup

- Specifying 'planned land-use' under the allocation setup of OWI is very effective in accommodating approved housing schemes, declared commercial areas and roads under commercialisation policy, zoning plan provisions, or special approvals.
- Mostly PUSP preparation exercises are followed by a land-use classification and re-classification exercise in the established built up urban area. The re-classified land uses can also be specified as 'planned land-use'.
- Annual development plan (ADP) grants of infrastructure and services (I&S) section of TMA can be incorporated using the Infrastructure Control field of OWI. The infrastructure expansion approved under ADP can be reflected as the year by which any given parcel will have a given service.
- If the TMA has identified some areas which have to be developed on priority, that can be controlled by specifying Growth Pattern Controls fields where planners can allocate regions that have to be developed in phases of the next five years, next ten years and so on.

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5.5 Demand Scenarios

- In OWI, future demand of land for various uses is calculated based on population and employment. In Pakistan, spatial planners use the National Reference Manual to calculate this demand for various land-use categories. Planners' Key is a small spreadsheet-based application which calculates the land requirements using NRM standards and other relevant national regulations (Hussnain & Wakil, 2006). In the national context, this tool has been very effective in calculating future land demand based on

5.6 Suitability Scenario

- For an area which is declared as commercial under Commercialisation policy, the conversion of land-uses (i.e. residential to commercial) can be specified under the Land-use Conversion stage of OWI.

6 CONCLUSIONS

OWI appears as a promising PSS to bridge the prevailing utilization gap by eradicating the both demand as well as supply side challenges. The Muzaffargarh case study shows a very encouraging task-technology fit between peri-urban planning process and OWI functionalities. While there was a learning curve in understanding the underlying processes, the results were promising and have greater replication potential for urban planners in Pakistan provided sufficient measures are taken to generate wider awareness and capacity building. This research concluded that The Online WhatIf? (OWI) has demonstrated to be a very good fit in PUSP preparation. This PSS has provided a consistent and structured process to support planners interactively exploring and testing future land development options. This is useful practical approach in the PUSP preparation process. It further highlights that there exists a dire need to further research and either design or adopt complementary PSS(s) which can take care of the remaining plan making stages such as land-use classification/reclassification and land demand projections based on NRM and other national regulations.

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