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Selection of indicators and predicting the progress of sustainable urban development of cities of the Punjab, Pakistan

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Abstract

Pakistan has about 35% of the total population lived in the urban area, due to rapid urbanization and industrialization cities were facing several problems. This study illustrated the predictions of urban sustainable development of Punjab. Five cities of Punjab were selected i.e., Lahore, Faisalabad, Gujranwala, Multan, and Rawalpindi to address economic, social and environmental progress. A system dynamic approach was adopted to formulate, simulate and validate the urban sustainable development. Furthermore, development has been observed within the time period from 2014 to 2040 by using STELLA software. The output of the study indicates the overall degradation of the environment in all the cities. On the other hand, social and economic development was timely increasing. This study highlighted the indicators that are useful to determine the present and forecasted condition of cities and provides better practices for resource management.

Keywords: Indicator; Cities; Urban Sustainable Development; System Dynamic Modelling; Variables; Punjab

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1. Introduction

Sustainability has been developed conceptually and through practical applications that carry out a balance between the needs of the present generation and those of future generation (Jones, 2007; Cortesão et al., 2016; Tran, 2016). In an urban setting, urban sustainability can define a process of long-term integration, precaution, co-evolution, and interaction between environmental, social and economic subsystem (Camagni, 1998; Adinyira et al., 2007; Tran, 2016). It has been recognized that sustainability has three dimensions or subsystem: social, economic and environment, which is also known as a triple downline (Ekins, 2011; Huang, et al., 2015). Environmental sustainability deals with protection of the environment (Jacobs, 1993; Goodstein and Polasky, 2005), social sustainability concerns about the social well-being of people (Bwalya and Seethal, 2016), and economic sustainability aimed at realizing economic development (Ciegis et al., 2009; Schaltegger and Wagner, 2011), also intends to efficiently consumption of resources and make reliable for future generation (Blok et al., 2013). Many countries and international organization have been working since the early 90s on assessment of sustainability by means of specific indicators (Worldbank, 1997; Bottero and Mondini, 2003; Segnestam et al., 2003; Xu and Coors, 2012). With respect to urban area, the indicator approach provides useful information about the performance of sustainability of the system which helps in making anticipatory visions about the future trends of sustainability (Winston and Eastaway, 2008).

Cities play important role in economic and social activities but poorly perform in environmental conservation (Mori and Christodoulou, 2012; Albino et al., 2015; Kitchin et al., 2015). Alarming increases in the city population, consolidated massive conurbations of more than 20 million people, predominantly in Latin America, Asia, and Africa. Globally the urban growth was 746 million in 1950, which increases to 3.9 billion in 2014, a number will increase to 2.5 billion by 2050 (Alfonso Pina and Pardo Martinez, 2016). The urban growth of the developing countries will absorb 95 % of the population by 2030. As compared to world population, 46 percent of the population living in the urban area of Asia. Pakistan is one of the countries in which 35% of its population lives in cities (Shirazi and Kazmi, 2016). Worldwide urbanization and industrialization have been associated with the environment (Dasgupta et al., 1999; Lukac et al., 2010), which consumes energy and raw material and generate waste also discharge pollutants by misuse of resources and land development, these are the consequences of the greenhouse effect and ozone depletion (Hart, 1997; Mehta, 2002; Huang et al. 2005; Madlener and Sunak, 2011). Moreover, social problems such as high crime rate, public safety also disturb the cities quality of life (Huang et al., 1998; Harvey, 2010; Long, 2016). This is important in perspective of developing countries, where urban growth was going on very fast and the need for actual tools to predict the future sustainability and understand the issues of related to social, economic and environmental factors.

System dynamic and analysis modeling of sustainable urban development were extremely important to understand and address issues associated with economic, social and environmental factors/subsystem (Lektauers et al., 2010). Though, it is challenging to get preferred prediction accuracy, because cities have a system of dynamic organized complexity and numerous variables that all affect each other. Variety of factors are associated with environmental conditions, urbanization, climate change and consumption of resources need to measure all together in a simulation model (Sorman and Uras, 2007). Hence, System dynamic

approach helps to understand the complex interrelationship between the variables of the system (Naimi and Voinov, 2012). There is increasing literature on applications of system dynamics modeling in urban development; (Shi and Gill, 2005) Shi and Gill (2005) developed a system dynamic model to explain the interaction of ecological agricultural development with the effect of long-term ecological, economic, institutional and social components in Jinshan County China. (Güneralp and Seto, 2008) Güneralp and Seto (2008) developed a simulation model for the interaction of economic, social and environmental to analyze environmental benefits and challenges of urbanization. (Feng et al., 2013) Feng, Chen et al. (2013) constructed a system dynamic model for energy consumption and trends carbon dioxide emissions for Beijing city in China. (Saysel and Barlas, 2001) Saysel and Barlas (2001) presented the dynamic simulation model on long-term accumulation of salt on irrigated lands.

The study explores the fundamental relationship between environmental, social and environmental factors, which helps to forecast the quality of life in urban regions. Cities of Punjab such as Lahore, Faisalabad, Gujranwala, Multan, and Rawalpindi was taken as a study area, a feedback loop structure was developed based on the framework of STELLA software, which presented a platform for predicting the trends of quality of life from 2014 to 2040. The system dynamic modeling will enthusiastically improve understanding on the basic interlinkage and their impact on future sustainable urban development. This provides necessary information for Punjab's future urban planning and highlighted possible suggestions for environmental conservation and socio-economic development.

2. Study area

Lahore, Faisalabad, Gujranwala, Multan, and Rawalpindi were selected with respect to the urban population to estimate the urban sustainable development among them. Lahore has a population of 7,684,000 million (GOP 2014) and located on Longitude: 74° 20' 37" E; Latitude: 31° 32' 59" N. The city is the center of economics, politics, education, and culture. Faisalabad lies on Longitude: 73° 5' 0" E; Latitude: 31° 25' 0" N and has an urban population of 3,142,000 million (GOP, 2014), it is known for numerous of industrial facilities, agriculture, and trade. However, Gujranwala situated on Longitude: 74° 11' 32'' E; Latitude 32° 9' 15'' N, with urban population 2,441,000 million (GOP, 2014). The city is the center of industries facilities and commercial activities, which play a major role in the economy of Punjab. Multan is the one of the populated city of Punjab that situated in flat alluvial plains which are known for good agricultural purpose. The city lies between Longitude: 71°26'E; Latitude: 30°12'N with an urban population of 1,824,000 million (GOP, 2014). Rawalpindi located in Potohar region lies on Longitude: 73°04′04″ E; Latitude: 33°36′02″ N, with an urban population of 2,622,000 million (GOP, 2014).

3. Methodology

Jay Forrester in 1956 introduced the system dynamics, is the well-established technique to understand, visualized and evaluate the complex dynamic system (Forrester, 1994; Forrester, 1995; Tang and Vijay,

2001; Lane, 2007; Coyle, 2009; Saeed, 2014). The study uses procedures and concept of system analysis to explore the dynamics of urban sustainable development. It simplified the complex real-world phenomena and incorporate the individual system into a general framework and explore their interactions in a model, thus providing a proper understanding of the whole system as well as urban sustainability (Lektauers et al., 2010). In this study, the system dynamic methodology was used to formulate, simulate and validate the urban sustainable development of Punjab cities. The model development process involved a number of iterative steps Figure 2.

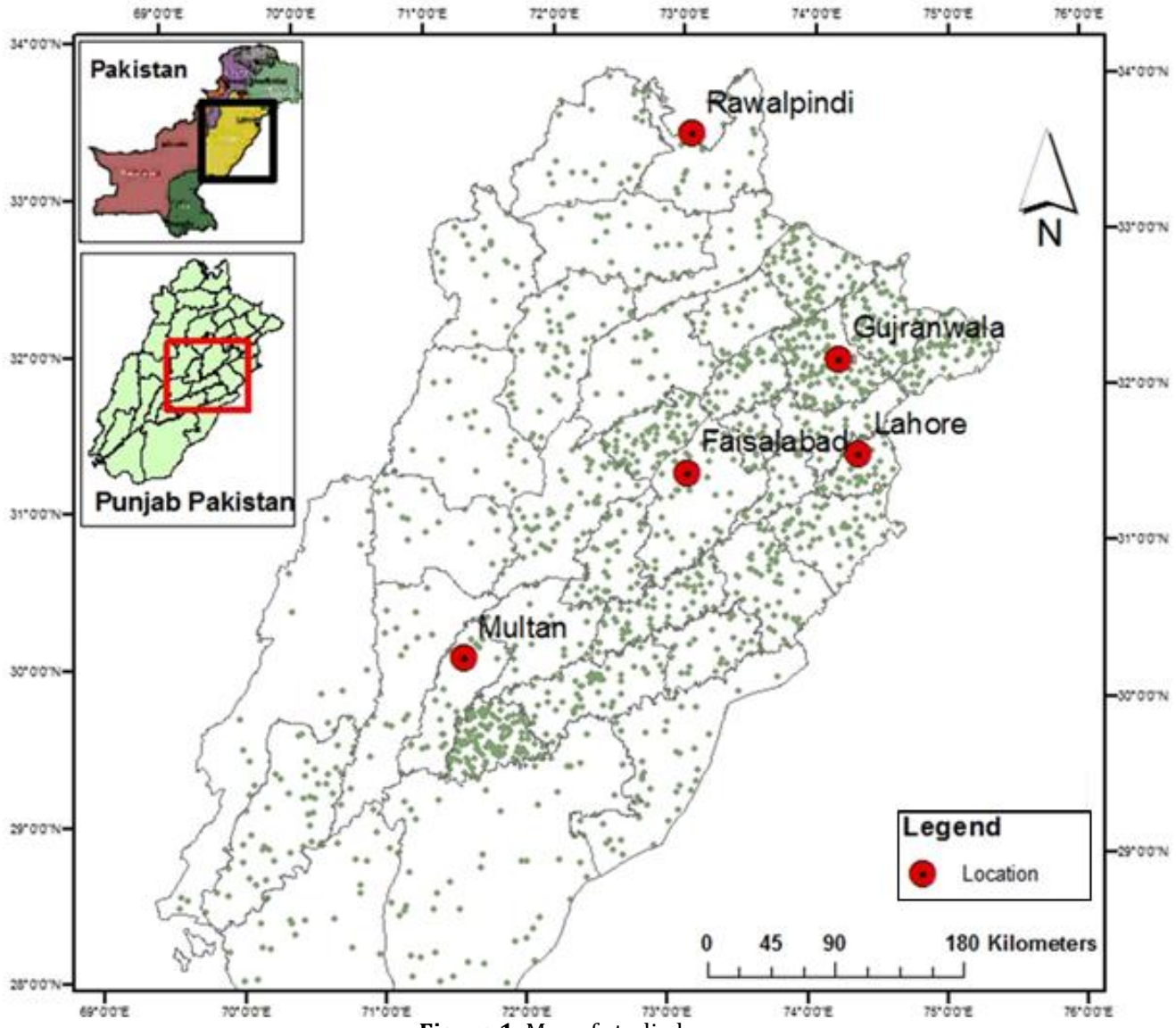

Figure 1. Map of studied area

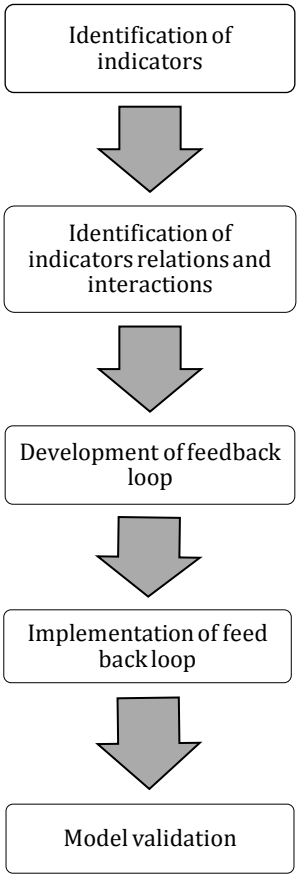

Figure 2. Procedure for development of system dynamic model

3.1. Selection of indicators for system dynamic model

The United Nations conferences on environment and development, held in Rio De Janerio in 1992 (Wilson et al., 2007), had already been highlighted the essential role of sustainable development indicators that appealed every countries international governmental and non-governmental organization to identify and develop the indicators of sustainable development in order to improve the information that base for decision making at all levels (UNCED, 1992). The initiatives of a compendium of sustainable development indicator mentioned more than 500 sustainable indicators (Böhringer and Jochem, 2007). The indicator is a tool to monitor the progress of sustainable development and provide manageable units of information on the environmental, social and economic condition, and also capture particular aspects in a way that indicates the change on a spatial scale with reference to time (Dahl, 2012). In order to select the indicators to represent the system behavior, this study examines operational indicators, which were used in the previous studies dealing with sustainable development.

In this study, 27 indicators were chosen grouped into three dimensions; Environmental, economic and social. From the basic dimensions the main indicators, sustainability, and quality of life were calculated. The triple down approach could cover a board range of issues that facing to attained sustainable development like healthcare facilities, education opportunities, degradation of the environment, demographic shift and

economic growth. Data were gathered from sources, i.e., Pakistan social and living standards measurements, Compendium of Environmental Statistics, District census report of Punjab and some data were collected from different department i.e., The Urban Unit, Environmental Protection Agency, Lahore waste Management and Punjab industries department. Summarizing the key issues the model framework was developed as shown in Table 1.

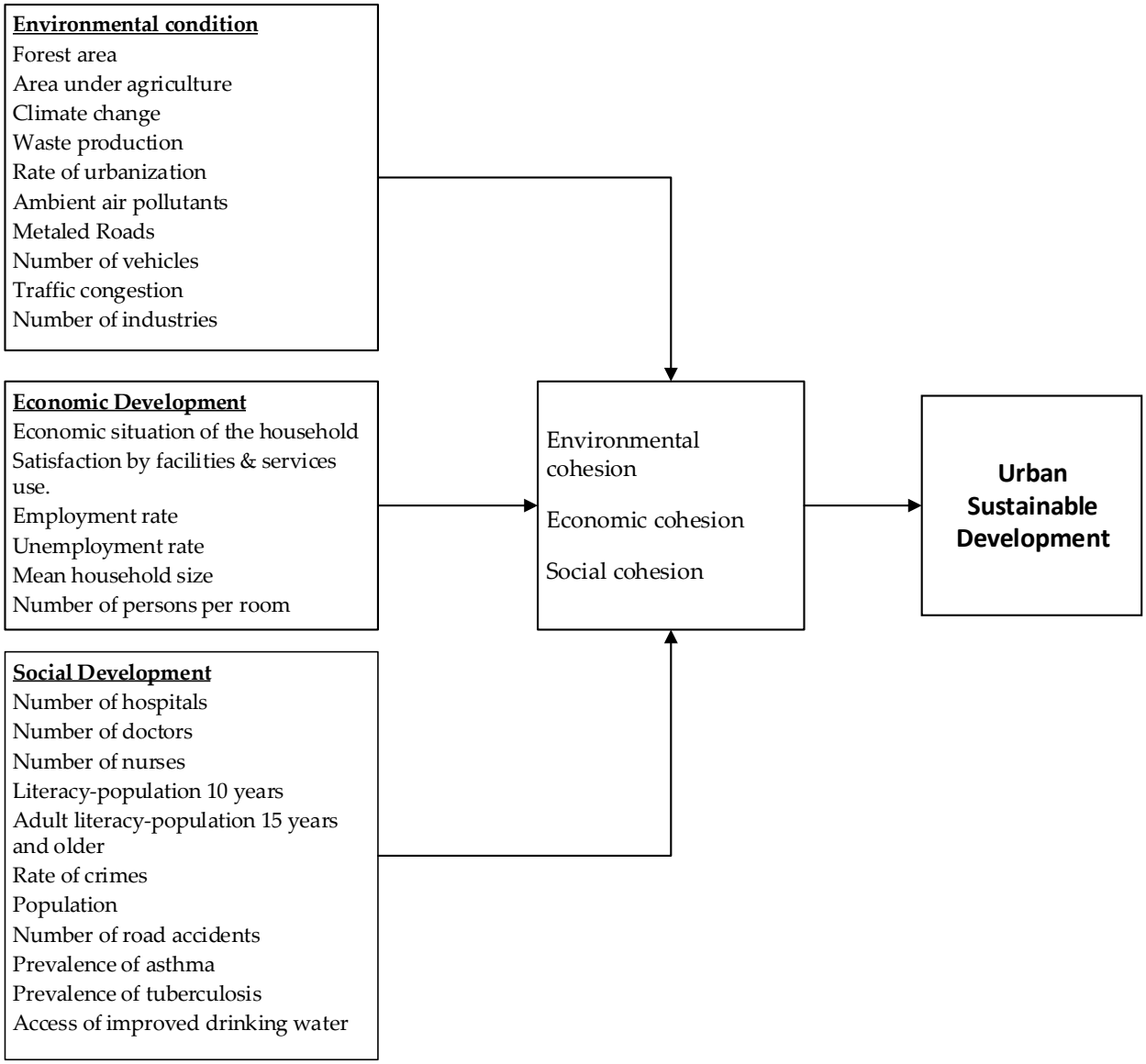

Figure 3. Group of indicators for system dynamic model

Table 1. Verification result of historical data with the established system dynamic model of five cities of Punjab

Cities	Urban population (per thousand)			Employment rate			Built-up Area			Literacy rate		
	A	M	e_i	A	M	e_i	A	M	e_i	A	M	e_i
Lahore	7522	7519	-4.04	99.77	99.7	2.05	576.4	576.6	4.3	79.37	79.97	-0.60
Faisalabad	3049	3049.7	2.22	99.03	98.9	-4.71	106.1	106.1	0.7	63.62	64.26	-0.64
Gujranwala	2340	2339.9	-0.28	102.4	102.3	-4.35	99.9	99.8	-2.4	80.62	81.03	-0.41
Multan	1770	1769.2	-4.28	101.7	101.0	-0.17	134.5	134.4	-1.9	55.55	56.51	-0.95
Rawalpindi	2536	2537.1	4.19	104.0	104.0	-4.19	77.7	77.68	-3.2	84	85.16	-1.16

3.2. Feedback loop model

The study develops system dynamics model by using STELLA software version 9.1.4, for estimation and prediction of urban sustainable development in cities of Punjab. The model is designed to run 26 years from 2014 to 2040 with a delta time (DT) equal to 0.25 year and benefits from using graphical programming which facilitates in representing the nonlinear dynamic system. System dynamic software like Stella support decision making the process by; developing the mental model, keeping track of complex interrelationships and feedback loops between the variables. While modeling system dynamic has capture positive and negative feedback and interaction of complex system, provided a transdisciplinary logical framework to address research problem in environmental, social and economic dimensions. The model consists of three components, which was structured and described as follows according to feedback loop as shown in Figure 4.

Figure 4 shows the feedback loop which illustrated that how different variables analyzed in the system dynamics of the cities of Punjab. Hence, this model adjusted to simulate the model and verify the relationship between the indicators. In this boundary, each indicator has definite effects on other indicators that generate the feedback loop in the model. The feedback loop breaks certain boundaries to produce the system thinking more logically and rationally.

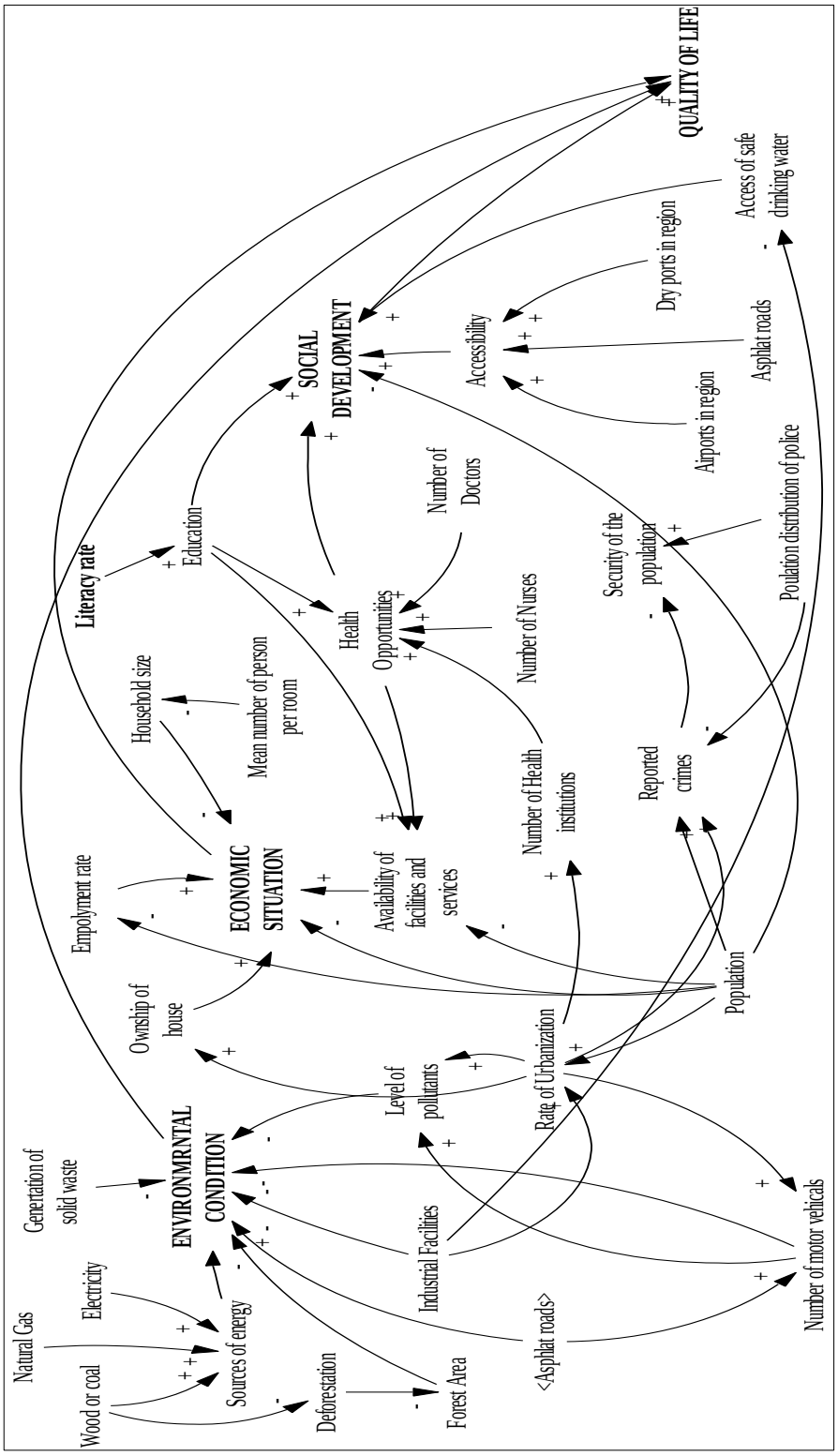

Figure 4. Mental Map and Casual Loop of the Model

4. Model validation

The calibration of system dynamic model is important for testing the feasibility and reasonability of simulation results. This can be carried out by comparing the model behavior with the real system behavior. The validation of system dynamic model is fulfilled firstly by comparing the real data in as well as simulated data in with real data in using equation (3) adopted from (Xu and Coors, 2012).

$$e_i = |\hat{y}_{it} - y_{it}|/y_{it}$$

where y_{it} is real data of indicator I in time (year) t, $\hat{y}$ is the simulated data of indicator I in time (year) t, and e_i is the relative error of the indicator. The model validation results for five cities data was shown in Table 1.

5. Results and discussions

System dynamic modeling used to examine the long-term future impact of the variables. In this section, the variable and the sub model was simulated and were compared between five cities of Punjab.

The environmental condition among the five cities was shown in Figure 5, indicated that the condition of the environment was declining in all the cities. Lahore was decreased from 65 to 45, Faisalabad had a rapid decrease from 62 to 56. However, Gujranwala revealed the decline of 65 to 45. While Multan showed decline trend from 60 to 40. Moreover, Rawalpindi displayed decrease from 63 to 55. Lahore and Gujranwala showed rapid move as compared to Faisalabad, Multan, and Rawalpindi. All the cities were degrading their environmental condition. Due to the reason all the cities have a high rate of urbanization and industrialization which causes more consumption of energy resources and a decrease of the forest. Settlements of industries in developing countries led to the development in various areas such as agriculture, automobiles, chemicals, manufacturing sectors, timber, bottling plant, gas, and coal. This has been developed the economy of Pakistan and living standard of the people, but it also led to degradation of environmental conditions like the extinction of rare species of plants, animals and the depletion of natural resources. The main causes of industrialization are deforestation which resulted in an increase of harmful effluents and pollutes the air, water, and soil. In Pakistan, there is also an issue of the presence of a large number of small industries and factories that don't have enough investment and depend on a government grant to run their business, usually disobeyed environmental regulation and generate a large number of toxic gases in the atmosphere. Forest area also has been rapidly converted to agricultural land, due to the comparative relation of farmers against landlord which continuously changes with demographic and economic pressures. Large landowners were more possessive to changes of economic like some financial returns, interest rates, government grants for credit of agriculture, inflation rate and prices of land. There is also the greatest threat to a plantation in the region, due to infrastructure development like highways, railways, and waterways, that is expected to terminate more forest than the plantations themselves. Governments should claim the new settlements of policies to control deforestation through inspections, clearing licenses and fines. In Pakistan,

industrial pollution was happening due to lack of effective policies and poor initiative of implementation, unplanned growth of industries that pollute air and water. Also, many industries depend on old technologies to produce high-cost end products and generate large amounts of wastes which often caused inefficient in the disposal of waste.

In contrast to environmental degradation, the growth of economic situation was continually increasing in all the cities. It has proved that economic growth was responsible for degradation of the environment. The economic situation among the five cities was shown in Figure 6. An increasing progress of economic was observed in Lahore from 30 to 110 during the year 2014 to 2040, Faisalabad, revealed that the economic development will increase from 30 to 100, whereas in Gujranwala had an increase of 25 to 105 percent. While Multan demonstrated the trend from 20 to 80 percent. Rawalpindi had amplified from 25 to 65. All the cities showed progress in economic condition. Lahore displayed high progress as compared to Faisalabad and Gujranwala, while Multan and Rawalpindi showed small progress. The economic development was moving towards sustainability, it can develop its potential by focusing on utilization of resources, coordination of institutions, resources of energy and investments. The industrialization and economic development go together in changing the pattern of consumption. The increasing number of vehicles in urban cities gives a valuable indicator of increasing consumption and growth of the economy. The increasing number of vehicles in Pakistan causes more fuel consumption, air pollution, traffic jams and demands for construction of the road. The rapid growth of energy production and consumption were resulted due to increasing numbers of population and its growing prosperity, and this trend is expected to intensify in future.

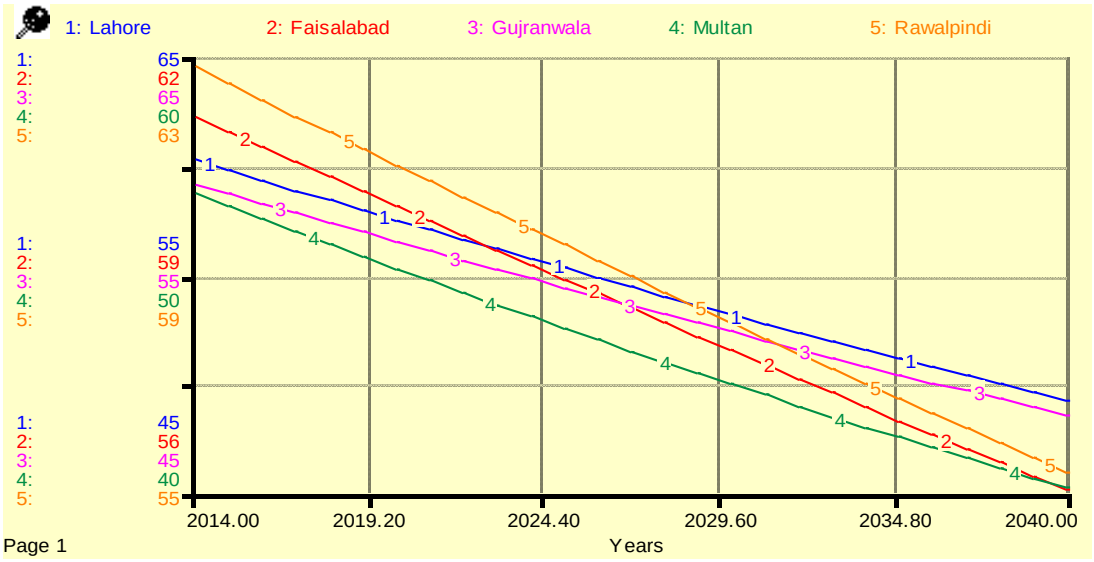

Figure 5. Environmental cohesion for five cities of Punjab

The social development of the cities from 2014 to the year 2040 was shown in Figure 7. In Lahore, the social development indicated the rise from 1150 to 1450. In case of Faisalabad, demonstrated the increase from 1100 to 1500. However, in case of Gujranwala, amplified from 1000 to 1700. While Multan city had an

increase of 1400 started 2014 and ends with 1800 in 2040. Similarly, Rawalpindi revealed the rise of 1220 in 2014 and 1250 in 2040. Among the cities, the Rawalpindi revealed rapid increase as compared to Faisalabad, Gujranwala, Multan, and Lahore. The result showed that all the cities were trending towards social progress. In this regards, there was positively increase in education and health facilities, also negative increase in high crime rate, epidemic diseases, and social injustices. With references to negative increases, the urban planner should emphasize on the equal distribution of resources, proper transportation, manage hospitality services and give proper precautions and knowledge about the environmental pollutants and diseases outbreak. Social development in all the cities was moderately increasing, here should emphasize on the education environment, improve the status of health institutions, social equality, and justice.

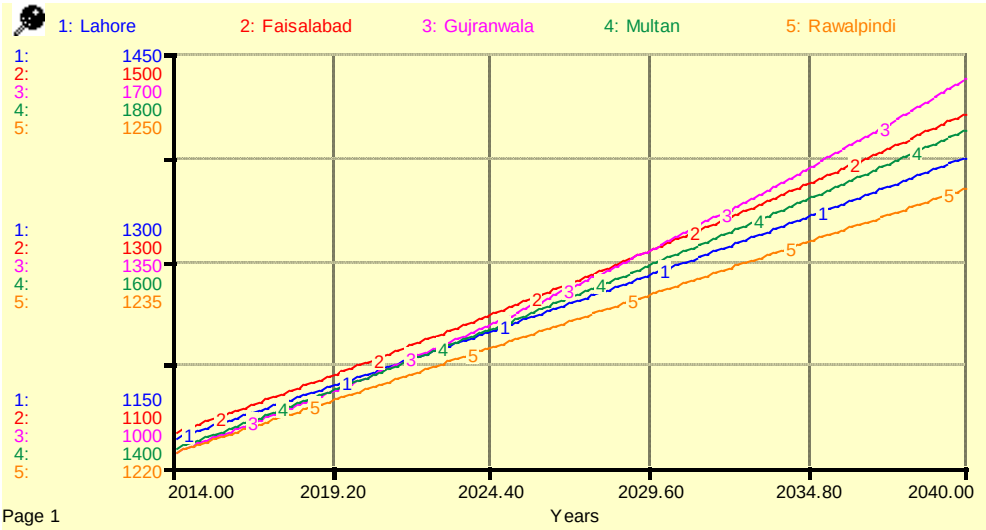

Figure 6. Social cohesion for five cities of the Punjab

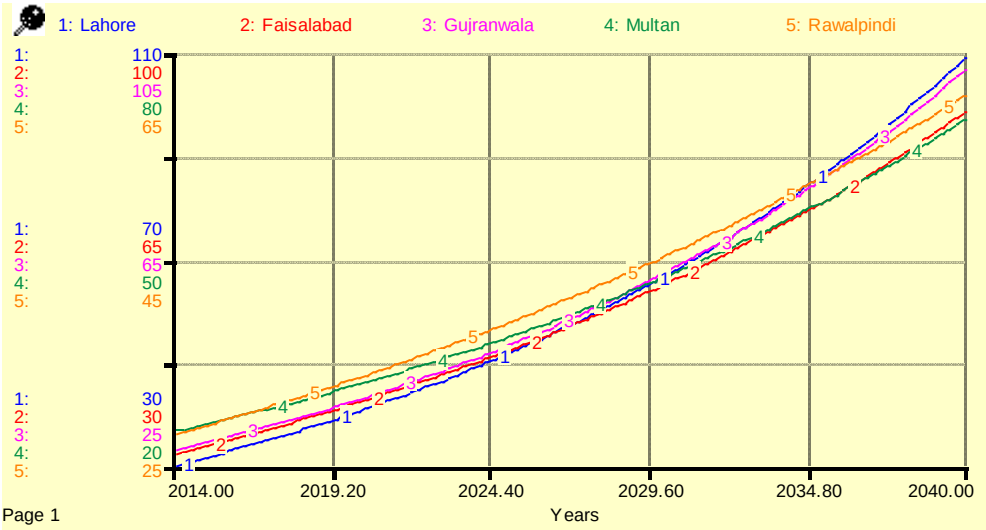

Figure 7. Economic cohesion for cities of the Punjab

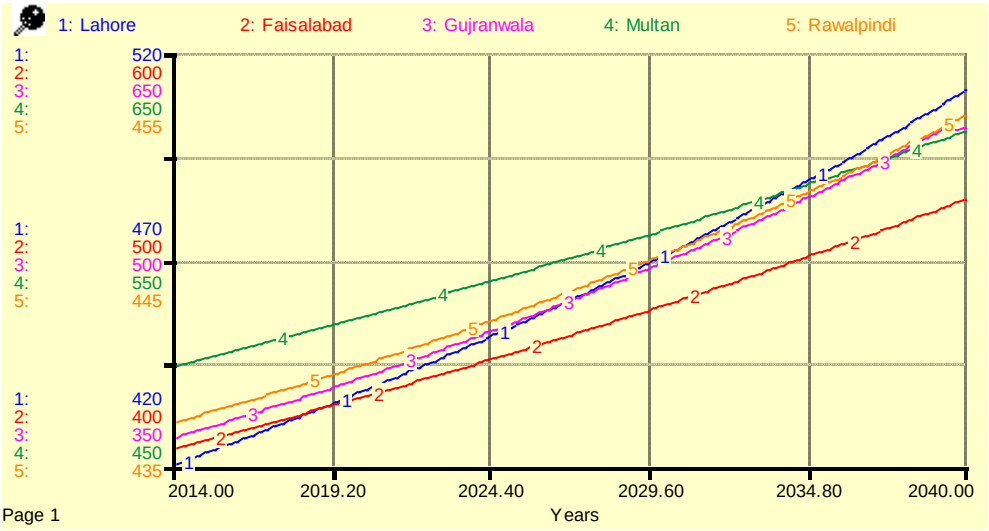

Figure 8. Overall quality of life for five cities of the Punjab

5.1. Comprehensive results of sustainable urban development

Cities of the Punjab were rapidly growing and expanding, thus the quality of life is very important to attained sustainable urbanization in Punjab. The overall quality of life was calculated as Lahore has increased from 420 to 520, Faisalabad has raised from 400 to 600, Gujranwala has increased from 350 to 650, Multan has moved from 450 to 650 and Rawalpindi has increased from 435 to 455. Among all the cities Faisalabad and Multan showed high trend Gujranwala. While Gujranwala showed less change as compared to Lahore and Rawalpindi. The environmental and social impact of human activities causes sustainability of local boundary to be linked dynamically to other areas through trades. Trades assists local population to exceed local carry capacity, which has a negative impact on the environment. In developing countries, the cities were referred as unsustainable due to reason they are in the early stage of development with high economic growth and ignore high accumulation of negative impacts on the environment. The numerous effects of living beings on the degradation of the environment as discussed in this study, it seems that if human beings want to be existent on earth, there have to give uppermost priority to save the environment and natural resources. There is need to control the growth of urban population and all types of pollution for a healthy environment. There should be the incorporation of environmental concerns in the development of agriculture, innovations of technologies, urban planning, resources management and growth of industries, the condition are expected to get worse in the future unless the significant measures are taken. The most important effort should be made in educating local leaders and public about the effects of increasing population on information, education and communication events. To preserve the green area, and remaining forest, social forestry, and afforestation programs must be applied at local level. The penalty should be enacted on the industries on disposal of wastes into the river. Moreover, emphasis on compulsory educating about the environment at the school level to make public aware of protection of the environment. The protection of the environment was

not only the responsibility of government the local leaders and local population should make efforts to eliminate the environmental problems.

6. Conclusions

Based on the concept of urban sustainability, the sustainability indicators were divided into three categories, judge the sustainability of urban areas in term of environmental sustainability and socio-economic distributional justices. Environmental indicators specified the limits of negative impacts of urban areas on the local environment, which accessed the sustainability of the city on the base of limits. Most of the existing system dynamic modeling has focused on the different aspects of sustainability. By contrast, the present study focused to establish the way that the system dynamic approach can be assembled to facilitate an integrated method to manage a complex system like urban sustainability. The purpose of adopting system dynamic approach was to inform decision maker to design environmentally sound, socially desirable and economically acceptable policies. This methodology improves the understanding of the dynamic of the systems, combines the variables of various disciplines for the operational analysis of urban sustainability. The present study is unique, that define urban sustainability within the interdisciplinary framework by adopting measurable sustainability indicators. The sustainability indicators identify the key causes of environmental, social and economic systems.

Cities of Punjab shows different results that presenting the root cause of the need to be improved to achieve sustainability in the overall cities of Pakistan. In this way, the increasing capacity for sustainable urban development requires promoting the sustainable use of ecosystem at both urban and regional level. This analysis could be expanded and make a future in-depth analysis of the variables that all expected to originate such method which provides a better understanding of system dynamics with more encompassing vision. In the end of system dynamic framework, the indicator output will supply continues guidance during the preparatory stage for developing national strategies on sustainable development which is necessary for new generation of citizen capable of promoting economically, socially and ecologically sustainable urban development. Initially, the limitation factor noted that the interrelation and link between the variables have itself generated a mental model which have been rather subjective, it depends upon a different way of perception and viewpoint that may change the entire system. However, the variables and indicators within the study have been selected from wide range of spectrum which enclosed all the dimensions of sustainability and has been comprehensively analyzed as possible. Another limiting factor of the study could be about assigning of equal weight to indicators during the assessment, because of the reason to not leave behind or bring forward any of the contributing indicators.

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