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# Design of Integrated Analytical Process Framework for Smart City Transformation based on Strengths-Weaknesses-Opportunities-Threats Analysis

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**Abstract:** The population growth, urbanization and environmental challenges especially in urban cites are pushing urban infrastructures to sustain the resources with smartness. Developing an intelligent and sustainable city is the way forward. The concept of making city 'smart' is evolving as a strategy to manage urban infrastructure and ease the urbanization challenges. Smart City (SC) transformation is a strategic process, which requires novelty in approach, planning, operations, networking and management of urban enterprises. In this paper, we have proposed three strategic phases of SC transformation process; i) SC vision and status assessment, ii) SC transformational initiatives and iii) SC development and implementation. The execution of every phase towards SC transformation is linked with each other and is impacted by multi-criteria factors which must be identified.

To strategize the SC transformation scenario, this work attempts to identify such factors for every phase of SC transformation on the basis of four dimensional strategic elements and decision making matrix known as Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis. Using four elements of SWOT model, 22 factors of significant importance have been identified. To analytically evaluate the dependency, independency and significant impacts among the identified SWOT factors, Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) have been used and four alternative strategies are developed. Finally, integrative framework is proposed to strategize the alternatives for SC transformation process.

**Keywords:** Smart City, SWOT Analysis, SWOT Matrix, Analytic Hierarchy Process, Analytic Network Process

## 1. INTRODUCTION

Environmental changes and growing needs with luxury life style are accentuating the world's natural resources towards the saturation point, which needs to be managed effectively and efficiently. Considering these challenges, there is viable urgency worldwide to become 'smarter' in how to manage the resources and efficiently utilize the infrastructure to accommodate the existing and future needs (Claxton, 2001). On the other side, with the rapidly increasing world's population and growing trends of migration towards urban cities, metropolitan cities are facing variety of risks and problems. Urban city infrastructure is generally in severe stress and will be pressed-hard further to provide basic services as demand may outstrips the supply, while emerging city will face sustainable development challenges (Childers, *et al.,* 2014). The urban growth and associated challenges have triggered the alarm of urgency to set smarter ways to cope such challenges.

Developing an intelligent and sustainable city is one of the ways to move on. To trigger this development, urban cities need to acquire the label of being 'smart city' as an icon of an intelligent and sustainable city (Kramers, *et al.,* 2014). However, the SC label is a fuzzy concept, as definition and concept has neither a single framework template nor any commonly agreed definition which fits to SC concept. The SC definition and conceptual framework depend on the systematic infrastructure and system application where this concept is intended for implementation. Before the concept of SC, digital city and intelligent city can be found in literature (Yang, 2014), focusing on the goals of urban information and embodied technological systems to have situational aware city. SC is a higher stage of digital and intelligent city. The concept of SC is driven by the next generation of technology dimensions by using Information and Communication Technologies (ICTs) infrastructure to build and integrate critical infrastructures and services for the cities. SC utilizes spatial information and intelligent sensing technologies to integrate and collaborate with urban information systems to efficiently manage the city resources to develop a sustainable city.

A SC signifies as instrumented, interconnected, and intelligent city (Shelton, *et al.,* 2014). Using sensors, personal devices, smart appliances, web data sources, data-acquisition and monitoring systems enable the data extraction and integration of real-world data as an application of instrumentation. Interconnection enables

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the integration of captured data into smart computing platform to analyze and monitor the information of city's critical infrastructure components and services. Artificial intelligence sets the system operational decisions to make detailed system analytics, system status modelling, optimizing the resources, and city services visualization. SC as an icon of an economical and sustainable city requires a deeper understanding of concepts, characteristics and its associated drivers. The initiatives of developing a SC as a model to exterminate existing urban city challenges and efficiently manage the resources to make city as an ideal place to live up has been the latest research area (Neirotti, *et al.,* 2014). For SC to adapt the fuzzy concept, SC visions, basic components and architectural framework are perceived accordingly (Aamir *et al.,* 2014). Most of the researches focus on SC importance and system applications while SC enabling factors and prospective challenges like transformation strategy and implementation needs more exploring. Even, the targeted research on SC enabling factors has specifically focused on orientation of specific applications and constraints. Thus, SC enabling factors are studied further by considering the different concepts and parametric analysing factors like strengths-weaknesses-opportunities-threats to set the strategic policy and decision making to customize the SC enabling factors.

Strategic planning has the crucial importance to set the long term success foundations, which depends on setting the future goals, identification of available resources, strategy formulation, setting the criteria's and strategic paths, analysing the success and failure potentials and different analytical matrix. Strategic planning may not be a straightforward task as execution of every strategic phase depends upon different factors and associated actors; each requires frequent assessment of target goals, defined roles, execution process and deliverables. For any successful strategy, flexibility and adoptability are the two major factors, which help to formulate the alternative strategy and substitution criteria, if required. The SWOT analysis is a preliminary decision-making support tool to systematically analyze the strategic conditions on the basis of internal strengths and weaknesses as well as on external opportunities and threats by identifying the coordinating constraint factors (Hill and Westbrook, 1997). If used appropriately, SWOT analysis can provide a strong platform for successful decision making and strategy formulation.

This work is an extension of our previous work (Halepoto *et al.,* 2015) where different parametric factors were identified and multi-criteria assessment was performed to strategize the SC transformation by using SWOT analysis. Taking this opportunity, our work is extended further to analyse the significance of identified factors for every phase of SC transformation on the basis of four dimensional strategic elements (Strengths- Weaknesses-Opportunities- Threats) and four paired SWOT matrix (SO–WO–ST–WT) to make alternative decision to be possible. Since most of the SWOT factors can be interdependent and interrelated, such factors may affect the overall strategic formulation, so there is a need to introduce an analytical approach into SWOT analysis to make system model more flexible and adoptable to different strategies, criteria's, sub-criteria's, and alternatives subject to understand the dependency or interdependency and relations among the identified factors. In relation to this object, two popular analytical approaches i.e. AHP and ANP have been used. Based on AHP and ANP approaches, an integrative process framework connecting the conceptual variants and coordinating constraints of SC enabling factors are proposed to strategize the SC transformation process.

The rest of the paper proceeds as follows: In Section 2, the general concept of SWOT case analysis is discussed. In Section 3, we have identified the significant parametric factors for strategic transformation towards label of being smarter city by using SWOT analysis. In Section 4, an analytical assessment of SWOT analysis is made to understand the dependency, independency and relations among SWOT factors identified in Section 3. In Section 5, two analytical structures are presented considering independency and dependency among the factors. In Section 6, an integrative analytical process framework for SC transformation based on SWOT analysis and SWOT matrix is proposed to strategize the SC transformation. Finally we have concluded the work and points to the future work in Section 7.

## 2. EXPERIMENTAL CASE ANALYSIS

### SWOT Analysis

SWOT analysis is a preliminary decision-making support tool to systematically analyze the internal and external elements (Vonk, *et al.,* 2007). By identifying the strengths, weaknesses, opportunities, and threats, one (i.e. institute organization, country etc.) can make decisions and formulate the strategies on the grounds of its strengths, eradicating its weaknesses, potentially exploiting opportunities and efficiently utilizing the opportunities to avoid the threats. The strengths and weaknesses are related to internal considerations while the opportunities and threats are identified according to external assessments (Dyson, 2004). Similarly strengths and opportunities are attributed as positively influenced while weaknesses and threats are attributed as negatively influenced elements. Overall, SWOT analysis can highlight the most relevant internal and

external elements in prospective of positive and negative attributes referred as SWOT elements as shown in **(Fig.1)**.

The SWOT elements and their potential assessment and utilization can be analysed from economic, ecological, technological and social sustainability prospective (Halepoto, *et al.,* 2014). However, its basic objective in the planning process is to be used as a decision support tool to formulate the strategy by analyzing the internal and external elements. On the basis of internal, external, positive and negative attributes of SWOT elements, the dependency, independency and relationships among these elements can be established and linked to generate a SWOT Profile and Matrix. Using SWOT profile, four different pairs of SWOT elements can be formulated as shown in **(Fig.2)** and can be represented into matrix form as:

$$SWOT\ Matrix = \begin{bmatrix} SO \\ WO \\ ST \\ WT \end{bmatrix} = Alternative\ options\ or\ stratgies$$

The coordination and synchronization between internal and external elements to formulate an adoptable strategy is challenging task. The SWOT matrix can simplify this task by producing different alternative options or strategies by making different combination of SWOT elements as shown in **(Fig.3).**

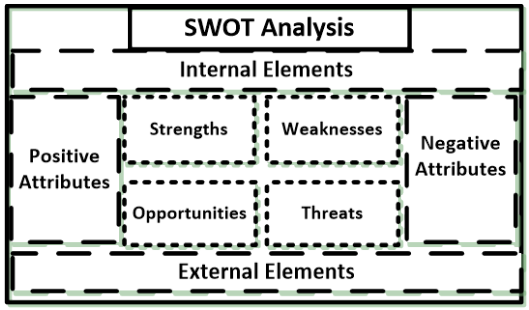


**Fig.1. SWOT Analysis –internal and external elements with positive and negatives attributes**

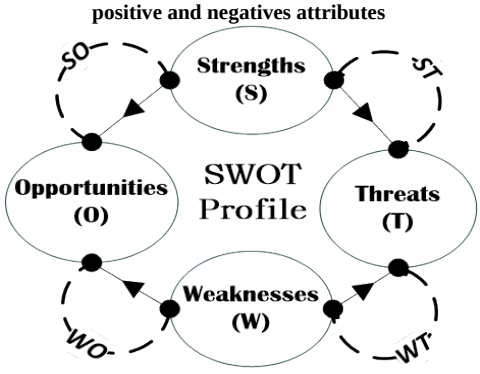


**Fig. 2. SWOT Profile - elements inner dependency analysis**

These four SWOT matrix pairs are responsible for; i) the coordination of positively attributed internal elements (strengths) with positively attributed external elements (opportunities) will generate strengths-opportunities (SO) matrix strategies to potentially utilize the internal strengths to take advantage of external opportunities, ii) the negatively attributed internal elements (weaknesses) with positively attributed external elements (opportunities) will generate weaknesses- opportunities (WO) matrix strategies to improve the internal weaknesses by taking advantage of external opportunities, iii) again the coordination of positively attributed internal element (strengths) with negatively attributed external element (threats) will generate strengths-threats (ST) matrix strategies to use internal strengths to avoid or reduce the effects of external threats, iv) lastly the negatively attributed internal element (weaknesses) with negatively attributed external elements (threats) will generate weaknesses- threats (WT) matrix strategies to set as defensive tactics intended to reduce the internal weaknesses to avoid external threats.

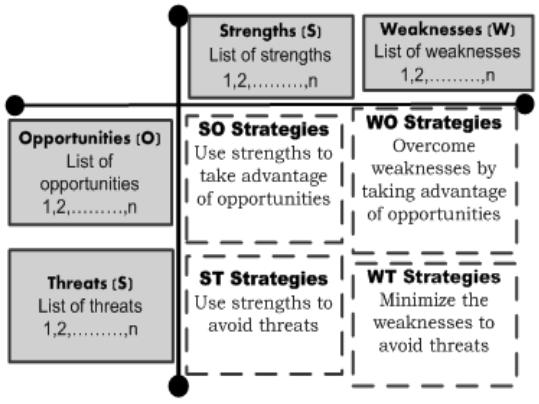


**Fig.3. SWOT matrix for producing alternative strategies**

## 3. SWOT ANALYSIS OF SMART CITY TRANSFORMATION

Once, the goal of transformation towards SC is decided, the intended city must evaluate its basic requirements, opportunities and set the clear objectives, prioritize the development efforts, and quantify the success and failure metrics on the road to SC transformation process. In this work, concept of SWOT analysis is used to identify the factors which are significant for city to being labelled as SC. The SC transformation has been divided into three phases: i) SC vision and status assessment, ii) SC transformational initiatives and iii) SC development and implementation. Since SC transformation is a gradual and iterative process so each phase of the transformation process should be analyzed very closely, as completion of every phase is the start-up of next phase, therefore the progress must access critically and flexibly. For every phase, some significant factors have been identified on the basis of SWOT analysis. The subsequent sections discuss these identified factors in detail.

### 3.1. SWOT analysis of SC vision and status assessment

The concept of SC is becoming the orientation of urban city development to endorse the city modernization and competitiveness. SC strategic vision is to have smart government, smart citizens, smart infrastructure, smart economy, smart environment, and smart mobility as the carrier of efficiently utilizing the resources, restructuring and upgrading the infrastructure, boosting the industrial revenue, stabilizing the economy and sustainable environment (Kehua, *et al.,* 2011). A successful SC can be realized either by bottom up means or top down approaches (Al- *et al.,* 2009), but active and positive participation of every relevant stakeholder is crucial. On the road to SC vision and status assessment to achieve the target objectives, it requires a thorough understanding of the different constraints and interconnections among individual and collective social and technical factors. In this work, we have identified such set of factors by using SWOT analysis, as discussed below.

*A. SC vision and status assessment – Strengths*

*1. SC is a higher stage of digital and intelligent city:* A well-functioning urban city and ICT infrastructure is compulsory part of SC concept but not enough to be considered as a SC, which is a step forward concept, requires integration and collaboration of urban information and management systems with ICT applications, such as Internet of Things (IoT and cloud computing. In the role of digital city concept, SC step forwards as the "information highway" utilizing remote sensing (RS), global information system (GIS), and global positing system (GPS) to capture and consolidate data systematically and form 3-dimensional (3D) functions to monitor data and take decisions accordingly. Based on intelligent city concept, SC exploits the intelligent information network to share information and resources based on information technology (IT) platform, such as artificial intelligence, intelligent sensing and decision systems to function efficiently.

*2. Well defined and realistic goals:* SC transformation must have well defined and realistic goals, although approach and roadmap can be different subject to particular case and application, depending on the specific requirements and resources availability. Apart from some specific goals, long term goals of developing SC is to promote IoT platform, cloud computing, public service information system, smart collaboration of technological components with political and institutional components, promoting citizen centric government, smart economy, strong market and business values, strengthening the overall city planning and operation.

*B. SC vision and status assessment- Weakness*

*1. Citizen's awareness and involvement factor:* Human capital is the progressive part of SC driving force, thus human capital participation should be the starting point rather than blindly considering that ICT and technological advancement will transform cities automatically. SC can be constructed on the smart combination of SC concept adoption by citizens and self-modified activities of situational aware citizens in a forward-looking way. Smart citizens of SC are not only characterized by the educational qualification but also by social interactions beyond the concept of 'personal life' to be connected with outer world issues. The existing urban city problems can be solved by smart solutions from smart citizens by means of citizen's awareness, social involvement, training and skills development, creativity, flexibility, open-mindedness, ethnic and social plurality and collaboration between stakeholders.

*C. SC vision and status assessment- Opportunities*

*1. Citizen-centric Governance:* Governance as one of the key enabling components for SC is responsible to make sure the participation and services collaboration among different functional sectors and stakeholders such as political forces, business communities, academics and voluntary organizations to manage resources more effectively to better serve the citizens. The significant spirit of such governance should be based on citizen-centric, citizen-driven approach to give citizens information access about ideas, visions, objectives, priorities, and strategic plans of SC and actively engage them in decision making and services using E-governance concept.

*D. SC vision and status assessment - Threats*

*1. Economic uncertainty:* The inconsistency in national and international rules and regulations related to economic policies cannot help to scale up the SC initiatives. Lack of appropriate and systematic approaches and metrics for reporting and verifying the investment returns is a valid concern, as depleting finances are affecting the overall public investments (Halepoto, *et al.,* 2005). The unstable financial situation, lack of credits and financial institutions regulation are limiting the available cash flows, thus slowing down the investments in new technology domains like SC.

*2. Political elements and policy contexts:* Policy context is important to understand the SC initiatives, comprises of political and institutional elements. SC transformation requires technological elements interface with political and institutional elements. Under the political dimensions, historically, the interaction between the private and public sectors is fairly complicated. One often observes that when it comes to

decision making, ownership and responsibilities are heavily intertwined. This can potentially hinder the SC development, so such decisions and execution process within smart cities needs to be institutionalized.

### 3.2. SC transformational initiatives

Once, SC vision and status assessment is performed by having SWOT analysis, a foundation stone has been laid down on the road to SC transformational initiatives, but still it may take many years to become truly 'smart'. SC initiatives must be conceived as an integrated approach to group all the stakeholders to play their prospective roles individually and advances with collective skills and capacities to strengthen the city management to improve city service and functionality. Detailed SWOT analysis needs be carried out at the time of transformational initiatives as certain potentials can only be materialized and mobilised if citizens and other stakeholders are well aware of SWOT elements before system take-offs.

*A. SC transformational initiatives- Strengths*

*1. Technological innovation and integration:* ICT has transfigured human's aspects of thinking, the way ubiquitous sensing and instrumentation, control and optimization, networking and service integration and wireless connectivity have converged, it has really made the citizens more situationally aware and smarter than ever. Smart ICT revolution and technology advancement have already set the required platform for SC concept due to following reasons.

Firstly, the development of fourth generation mobile communication technology has already customized the technical basement especially for broadband applications and high speed transmission of information, which signifies the geospatial spaces for SC developments. Secondly, the data collection, access and exchange issues are now easier with the introduction of IoT, which enables identifying, locating, positing and managing network by transmitting and exchanging information between things by defined protocols through sensors, radio frequency identification devices (RFID) and GPS. Thirdly, cloud computing being the distributed computing mode, sets high efficiency of information processing and information diffusion is facilitating the users living status and public accessories by using IT services and infrastructure, computing platform and software modules. Lastly, information system integration platform is providing the flexibility of wide range data integration specially the integration of urban information system to offer access to geographic and demographic database for SC.

*2. Government involvement:* For the success of every project or initiative, government or authority stakeholders need to be on the front hand to take the driving seat, same is the case with SC to promote the urban management and information system. Government needs to motivate the citizens, business communities, public and private enterprises to take active part in SC transformation process by sharing information, development plans, process frameworks, and implementation scenarios so that the collaboration can be smoothen.

*3. Strong business market opportunities:* Any project initiative requires an economic competitiveness, innovation business opportunities, trademarks entrepreneurship and coordination between business markets. Understanding the importance of SC for sustainable development, the European Union has substantially placed a budget of € 107,180,000 for SC development and related projects in on-going horizon 20-20 project for 2014-2020 periods (Horizon 20-20 Call for proposal).

*B. SC transformational initiatives- Weaknesses*

*1. Managerial and organizational issues:* The active involvement of leading organizations is essential for SC initiatives. On one side, the successful initiatives require managerial and organizational innovation which cannot be achieved without interdepartmental collaboration, while on the other side; managerial and organizational interoperability is the mandatory part of SC initiatives which requires dynamic leadership skills.

*2. Cross-sectorial cooperation challenges:* It is almost impossible to even initiate SC concept individually. Identification of team players is of significant importance because even initiatives requires cross-sectoral cooperation between different stakeholders, communities, organizations and business enterprises, inter-departmental coordination and integration across governmental sectors. Also, there is a need to break information sharing and exchange barriers so every stakeholder remains updated about the progress as it happens accordingly.

*C. SC transformational initiatives-Opportunities*

*1. Institutional interactions:* SC transformation promises generous interactions between different institutions, especially technological elements interaction with political, institutional and transitional elements. Political elements represent endogenous political components harmonized by exogenous agendas and strategies. Legal and regulatory barriers are confiscated by institutional elements, while a transitional element covers visions, leadership, and organizational development.

*2. Innovation and Entrepreneurship:* The utilization of IT intelligence cannot be the only objective of SC but the integration of different resources are required to develop a sustainable and liveable city, which not only

be innovative in information and management but must consider the human interactions and interest intact. During sustainable city construction, creation of job opportunities, workforce development and entrepreneurship will lead a significant improvement in productivity, and will also set high degree of economic competitiveness.

*D. SC transformational initiatives - Threats*

*1. Lack of universal standardized frameworks:* There is no "universal solution" to ensure the success of a city in its path towards 'smartness', instead, a set of transformations has to deal with in order to take into account of different aspects. Many cities worldwide have launched initiatives to become smart cities, and each case is different.

*2. Information security and risk control:* SC has indubitably raised certain questions regarding the information security and associated risks in the process of development. The issues like data storage security, protected information processing, public information property rights are all important issues, which must be addressed systematically so that citizen's right towards information security can be guaranteed.

### 3.3. SC development and implementation

The SC development strategy and implementation is different scenario subject to SC vision, adoption, initiatives, and overall progress. The development strategy of SC is important by the following three reasons. Firstly, it can clarify the strategic difference about specific strategy that how it will perform better than other SC development strategies; secondly, it can help city management to cope with the changing environment; thirdly, strategic management helps to coordinate city's management and people's efforts working in the same directions.

*A. SC development and implementation- Strengths*

*1. Applications integration platform:* The orientation of cutting-edge technology such as IoT, cloud computing, advance signal processing, sensing and instrumentation, RFID, and ubiquitous informational network applications like RS platform, GPS, GIS, spatial-temporal data services and urban spatial information system have open the smartness gates. The integration of these cutting edge technologies and information system applications have set the required platform base to take benefit of complete information about city's geographic and demographic database, and macroeconomic database to develop a sustainable city that will surely address the future needs.

*B. SC development and implementation- Weaknesses*

*1. Lack of multi-source and multi-temporal data:* One of major concerns about existing urban information systems is lack of different types of information from different sources to make temporal and spatial data analysis. The information data source depends on RS, GIS data mapping and 3-D model of city areas. Multisource and multi-temporal data with temporal and spatial data analysis can assist city administration and stakeholders to make for better decisions and system management.

*2. Lack of real time decision mechanism:* Lack of different types of information from different sources for high spatial and temporal analysis barricades the real-time information updates and future predictions which affects the real time decision support mechanism practically.

*C. SC development and implementation- Opportunities*

*1. Large scale space–time and service platform:* Sensors, controllers and computing terminals are the major sources of acquiring SC spatial information from different service platforms which must be operated in coordinated manner. As SC information contains large amount of structured (atmospheric data like temperature, geographical coordinates and so on) and unstructured data (pictures, video and audio files), so the storage and management of such huge amounts of data needs some special attentions, because misinterpretation of data can affect the city information services severely.

*2. Handling heterogeneous urban information system:* As SC spatial information is acquired from different sources, while data observation processing mechanism, data and location information are different (Channa, Memon, & Halepoto, 2013), so SC requires proper handling of such multi-source heterogeneous information system to continuously observe the information data and to be able to detect any abnormal event effectively as it happens.

*D. SC development and implementation - Threats*

*1. Data privacy and security issues: The* information sharing and exchange barriers need to be removed, but it does not mean that data privacy and information security could be compromised at any stage to allow unauthorized access to data. Cybercrimes and data encryption techniques are challenging the data privacy and information security, which must be taken to the highest level before massive scale deployment of sensors and data acquisition systems.

*2. Standards and interoperability issues:* To manage urban information system, usually different cities and organizations adopt different standards and models which create interoperability issues. For certain reasons this may looks logical but in broad prospective of SC deployment at wider scale commonly adopted standards and unified information models are required to be developed so that every stakeholder remains involved in urban information, infrastructure and services.

The broad factors identified from three phases of SC transformation using SWOT analysis are summarized in **(Table.1)** in notational form.

**Table.1. Identified SWOT factors and their notational representation.**

| Identified SWOT Factors | Notational Representation |
|---|---|
| Smart city is a higher stage of digital and intelligent city | $P_1(S_1)$ |
| Well defined and realistic goals | $P_1(S_2)$ |
| Citizen's awareness and involvement factor | $P_1(W_1)$ |
| Citizen-centric governance | $P_1(O_1)$ |
| Economic uncertainty | $P_1(T_1)$ |
| Political elements and policy contexts | $P_1(T_2)$ |
| Technological innovation and integration | $P_2(S_1)$ |
| Government involvement | $P_2(S_2)$ |
| Strong business market opportunities | $P_2(S_3)$ |
| Managerial and organizational issues | $P_2(W_1)$ |
| Cross-sectoral cooperation challenges | $P_2(W_2)$ |
| Institutional interactions | P2(O1) |
| Innovation and entrepreneurship | P2(O2) |
| Lack of universal standardized frameworks | P2(T1) |
| Information security and risk control | P2(T2) |
| Applications integration platform | P3(S1) |
| Lack of multi-source and multi-temporal data | P3(W1) |
| Lack of real time decision mechanism | P3(W2) |
| Large scale space–time and service platform | P3(O1) |
| Handling heterogeneous urban information system | P3(O2) |
| Data privacy and security issues | P3(T1) |
| Standards and interoperability issues | P3(T2) |

In **(Table.1)** the terms $P_1$, $P_2$ and $P_3$ represents 1st, 2nd and 3rd phase of smart transformation process, while labels S, O, W, and T represent strengths, weaknesses, opportunity and threats factors respectively and subscript numbers (i.e. $_1$, $_2$ and $_3$) in combination with S, W, O and T labels indicates the total number(s) of factors.

## 4. ANALYTICAL PROCESS REPRESENTATION OF SWOT MODEL

Although SWOT analysis is an effective way of conducting a situational assessment which may help to identify the factors in adopting or implementing any specific strategy for decision making but its standalone use has limited capacity to determine the linkages, direct or indirect relationships and significance of every individual SWOT factor in the strategic decision in relation to one another. To quantify these issues, it will be a good practice to analytically analyse the SWOT factors with the help of some kind of analytical approach. In this work, SWOT analysis is carried in combination with AHP and ANP approaches to quantify the impact of every SWOT factor in decision-making and strategic planning.

### 4.1. Analytic Hierarchy Process Approach

AHP is a comprehensive unidirectional hierarchy based analytical approach to solve multi-objective, multi-criterion, and multi-actor decisions, which may involve certainty or uncertainty in decisions (Saaty, 1990). AHP approach considers both deductive and inductive factors rationally. Unlike the SWOT analysis, AHP approach considers that the presented factors in hierarchical structure are practically independently (Harker, 1989) but this may not be a realistic presumption as a whole. When SWOT factors are structurized into AHP form, it represents more realistic understanding of the system application, overall goals, adopted criteria, defined sub-criteria's and possible alternatives on the basis of identified factors.

The most significant part of AHP approach is its ability to present a complex problem with a simplified hierarchy structure including: target goal(s), criteria(s), sub-criteria(s) and possible alternative options. The presented hierarchy structure in combination with SWOT model comprises of four levels is shown in **(Fig.4)**. The hierarchy structure is defined in such a way that the target goal (best strategy) is placed at the top of hierarchy, while the criteria (SWOT factors), sub-criteria (SWOT sub-factors) and alternatives (alternative strategies) are placed in second, third and fourth tiers respectively in descending order. The AHP approach provides a comprehensive framework which tactically assists the strategic decision makers to find and set the suitable ways that suit the targeted goal according to problem understanding and orientation within the defined criteria's and re-evaluate the alternative strategies accordingly.

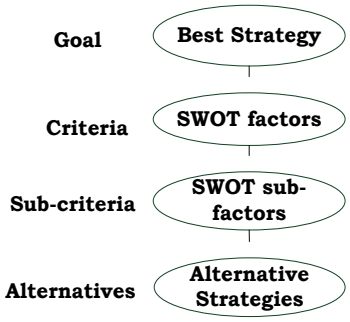


**Fig.4. Hierarchical representation of the SWOT model**

### 4.2. Analytic Network Process Approach

Many of the problems and decision cannot be presented in unidirectional structured hierarchically in straightforward way because of the functional dependence and multi-directional interaction with lower or higher components. This kind of structuring problem may also require feedback path between different factors and associated actors. Traditionally, AHP being the linearized top to down structure is restricted to solve the problems of independency on alternatives while for the problem of dependency between the factors or alternatives requires diversity in analytical process, capable of handling the functional dependency among

decision levels and attributes and the equally capable of faciliting the feedback path among different factors and associated actors. ANP offers network and cluster based feedback structure with non-linear characteristics that extent in multi-directions (Sevkli *et al.,* 2012). A multi-directional feedback representation of AHP with SWOT model is shown in **(Fig.5).**

ANP feedback method is multi-directional approach which replaces unidirectional hierarchal structure with networks representing the relationships between the higher or lower, direct or indirect factors. This makes ANP method a multi-purpose decision approach which considers the mutual and interdependent relationships among factors and sub-factors, criteria and sub-criteria and alternatives to solve more complex decision-making problems. Similar to AHP, the presented network structure of ANP also comprises of four levels, representing the goal(s), SWOT factors, SWOT sub-factors and alternatives strategies respectively with inner dependence within clusters in top to bottom structure as shown in **(Fig.6).**

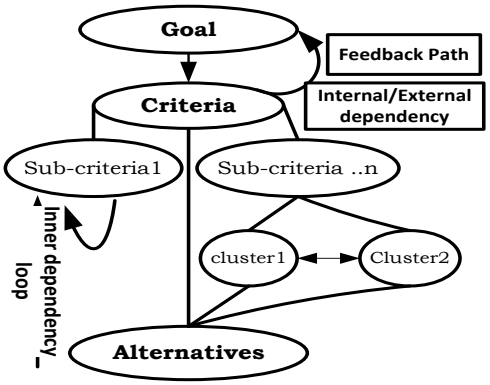


**Fig.5. Generic representation of ANP structure**

The "best strategy" is placed in the higher tier of the ANP model while SWOT factors are placed into the second tier. At the third level, SWOT sub-factors are placed while alternative strategies are placed at the last tier. The multi-directional interaction capacity of ANP approach with lower or higher components allows feedback path and inner dependency loop across the factors. The dependency among different factors can be direct or indirect dependency. For the case of indirect dependency, there can be even different levels of indirect dependency among factors.

By considering all the possible interactions, mutual interdependences, complicated relationships, and feedback paths, ANP systematically evaluate all the relationships analytically. Different alternative solutions and strategies can be set by analyzing the impact of each factor on another factor using pairwise comparisons, so eventually this approach will strategically determine the comparative importance of different activities in a multi-criteria decision problem.

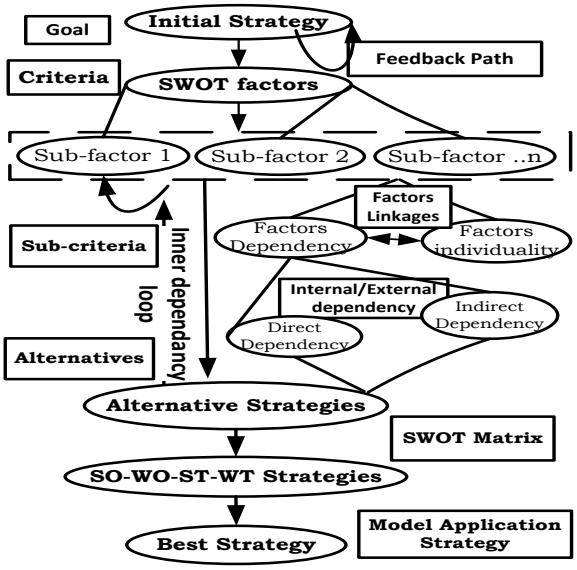


**Fig.6. Network representation of the SWOT model**

## 5. SWOT ANALYSIS BASED ANALYTICAL PROCESS FRAMEWORK FOR SMART CITY TRANSFORMATION

AHP being unidirectional hierarchy approach considers that the presented factors in hierarchical structure are practically independent to each other and there is no option of feedback path from lower to higher components. **(Fig. 7)** represents the 22 identified factors in Section.3 according to four SWOT elements (S, W, O, and T) in form AHP structure.

For the simplicity of understanding, SC vision and status assessment factors are represented by continuous line, dashed line identifies the SC transformational initiative phase and dash-dot line represents the SC development and implementation phase. It can be observed that with AHP approach the identified factors are assumed as independent to each other, but this can be a weak presumption because practically these factors may have some relationships.

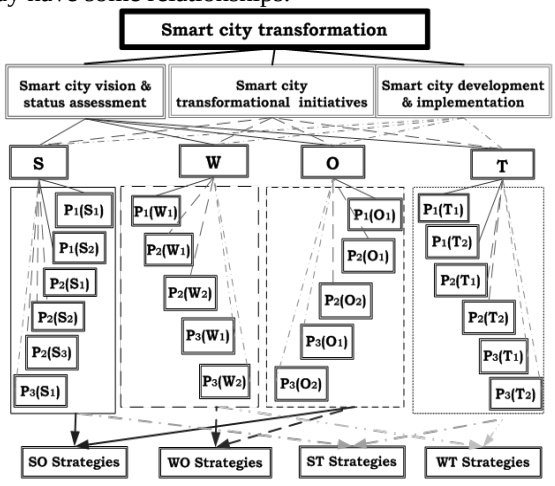


**Fig.7. Representation of identified SWOT factors for SC transformation in AHP structure**

The limited scope of AHP can be made broader by using different combinations of SWOT matrix (SO-WO-ST and WT). The SO strategies are presented by continuous line, while dashed line is used to highlight the WO strategies. ST strategies are represented by single dash-single dot line, while single dash-double dot line is used to highlight the WT strategies. The alternative strategies can help to assess the overall situation and re-assess the criteria in broader scope to make better decisions to come up with the best possible strategy. To represent the relationship among these factors, ANP approach can be used to effectively structurized these factors. ANP offers network and cluster based feedback structure that extends in multi-directions which ideally considers the mutual and interdependent relationships. The 22 identified SWOT factors can be related to each other by either having direct or indirect relations or functional dependencies to each other. Even, indirect dependency may have different scales. To make understanding easier, we have limited the scope of this work by only considering the direct dependency among the factors. The factors which can have direct dependency to other factors for SC transformation are listed in **(Table. 2).**

To present the clearer picture, the identified factors with direct dependency on other factors are also shown in **(Fig. 8).** For the ANP, the identified factors are grouped according to the three phases of SC transformation rather than four SWOT elements. From Fig.9, it can be observed that, some factors are more significant such as (($P_2(S_1)$, $P_2(S_2)$, $P_2$ $(W_2)$, $P_3(O2)$ and $P_3(T_2)$), as more than one factors directly depend on these factors. Once the significant factors are identified which are capable of affecting the overall goal in either positive or negative way, the strategy to transform towards SC can be re-strategize subject to assessment of the situation, defined criteria, and efficiently using the alternatives strategies.

**Table. 2. Direct dependency analysis of identified SWOT factors for smart city transformation.**

| SWOT Factor | Direct Dependency | SWOT Factor | Direct Dependency |
|---|---|---|---|
| $P_1(S_1)$ | $P_2(S_1)$ | P1($S_2$) | $P_2(S_2)$ |
| P1($W_1$) | $P_2(S_2)$ | $P_1(O_1)$ | $P_2(S_2)$ |
| $P_1(T_1)$ | $P_1(T_2)$ | $P_1(T_2)$ | $P_2(S_2)$ |
| $P_2(S_1)$ | $P_3(S_1)$ | $P_2(S_2)$ | $P_1(O_1)$ |
| $P_2(S_3)$ | $P_1(T_2)$ | $P_2$(W1) | $P_2(W_2)$ |
| $P_2(W_2)$ | $P_2(W_1)$ | $P_2(O_1)$ | $P_2(W_2)$ |
| $P_2(O_2)$ | $P_2(S_1)$ | $P_2(T_1)$ | $P_3(T_2)$ |
| $P_2(T_2)$ | $P_3(T_1)$ | $P_3(S_1)$ | $P_2(S_3)$ |
| $P_3(W_1)$ | $P_3(O_2)$ | $P_3(W_2)$ | $P_3(O_2)$ |
| $P_3(O_1)$ | $P_3(T_2)$ | $P_3(O_2)$ | $P_3(T_1)$ |
| $P_3(T_1)$ | $P_2(T_2)$ | $P_3(T_2)$ | $P_2(T_1)$ |

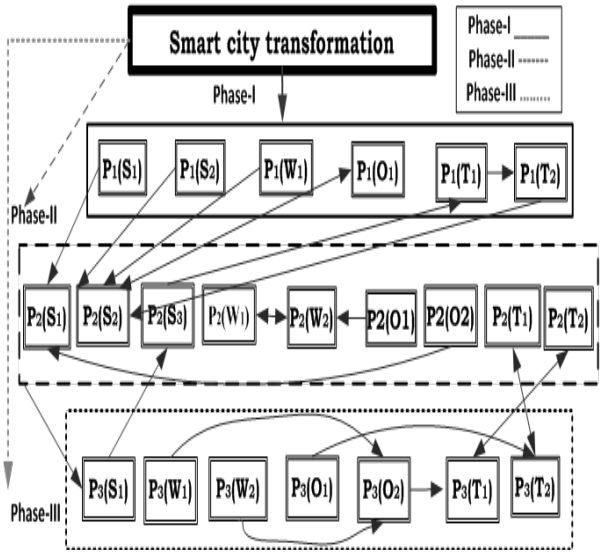


**Fig.8. ANP based direct dependency analysis of SWOT factors for SC transformation**

## 6. INTEGRATED ANALYTICAL FRAMEWORK FOR SMART CITY TRANSFORMATION

The integrated assessment of significant SWOT factors and four alternative strategies in analytical form can produce multiple strategies and practically makes easy to develop the integrative framework of SC transformation as shown in **(Fig. 9).** As a matter of fact, SC transformation should be flexible according to specific case scenarios but in general prospective, multi-criteria and different significant factors must be identified to strategize the transformation. This integrative framework can set the strategic priorities of SC by analysing the significant factors, which resulted to the adoption of simplified path and one of the best strategy is chosen to make transformation possible in the easiest manner.

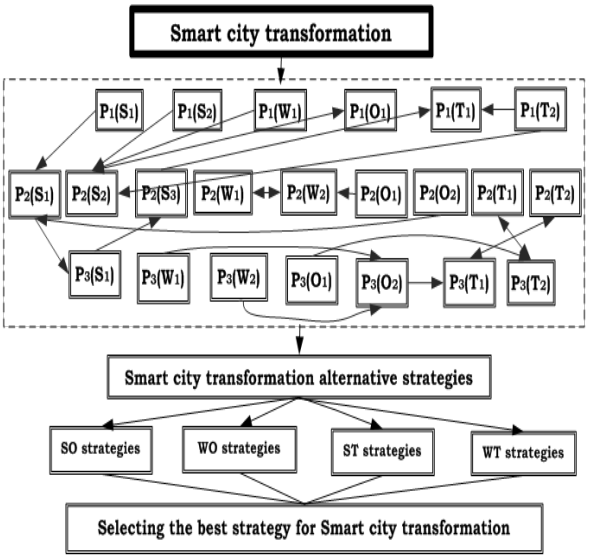


**Fig.9. Integrated Analytical representation of identified SWOT factors for SC transformation**

## 7. CONCLUSION

In this work, by using four elements of SWOT model, we have identified 22 factors of significant importance to strategize the path of transformation towards SC goal. Though SWOT analysis is well accepted tool for decision making and setting the policy directions but its standalone use has limited the capacity to quantify the issues of analytical assessment and mutual interdependency between different factors and associated actors. To identify the relationships among 22 identified factors, AHP and ANP approaches have been used and four alternative strategies are proposed by using SWOT matrix concept. An integrative framework for SC transformation is also proposed by combining the overall understanding of SWOT model, unidirectional representation of identified factor in form of AHP, establishment of direct dependency analysis and proposing four alternative strategies by ANP and finally conceptual framework of choosing best possible strategy for SC transformation is proposed.

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