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A Decision Support System for Information Technology Policy Formulation

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Abstract

The implementation of an effective ICT policy requires the development of material and intellectual resources to support good decision making by humans. In this paper, we examined and analysed Information Technology (IT) policy development process with a view to developing automated system supporting such process. The data used for this work were obtained through purposeful interview of five professionals and experts who are familiar with IT policy formulation in Nigerian environment. Some of the experts had earlier participated in policy design and formulation process at national level. The Hierarchical Input Process Output (HIPO) model was used to analyse various input (contributions of professionals and experts) and output (agreed resolution of the professionals and experts) of the system. The information obtained from the experts was represented using rule base techniques. The overall system was designed using the Unified Modelling Language (UML) and implemented using the Visual Prolog version 7.0. The metrics used for evaluating the system includes: processing time, decision process efficiency and cost effectiveness. We compared the result of our system with that of the traditional manual system in use. Our result showed that the DSS for policy formulation process enhances the decision output significantly when compared to the manual process where no DSS is used. Moreover, the quality of policy produced by our DSS system is more consistent when compared with the manual process.

Key words: decision support systems, policy documents, policy formulation, ICT.

1. Introduction

Information plays a very significant role in the life of mankind since the antiquity. However, in the mid-twentieth century, the role of information increased tremendously as a result of social progress and the vigorous development in science and technology. Trostnikov (1990) pointed out that, rapid expansion of a mass of diversified information is occurring, which has received the name “information explosion”. As a result, the need for a scientific approach to information and elucidation of its most characteristic properties has led to two principal changes in interpretation of the concept of information. It was broadened to include information exchange not only between man and man but also between man and machine, as well as the exchange of signals in the animal and plant worlds. New and emerging technologies have posed a great challenge to the traditional process of teaching and learning, and the way education is managed. Information technologies as an important area of study in its own right have had, and are still having a major impact across all curricula. Information Technology (IT) has provided access to a vast array of data challenges assimilation and assessment skills.

Increased access to Information Technology (IT) facilities in the home, at work, and in educational establishments, could mean that learning has become a truly lifelong activity, an activity in which the pace of technological change forces constant evaluation of the learning process itself. Communication on its own can be described as the process of transmitting and receiving ideas, information, and messages. In keeping with their complex nature and multiple applications, Information and Communication Technologies (ICTs) may be viewed from different perspectives. The World Bank defines IT as “the set of activities which facilitated by electronic means the processing, transmission and display of information” (Rodriguez and Wilson, 2002).

IT “refers to technologies used by people to share, distribute, and gather information to communicate through computers and computers networks”. IT can be described as a complex varied set of goods, applications and services used for producing, distributing, processing, transforming information, hardware and software, computer services and electronic media” (Marcelle, 2000). IT represents a cluster of associated technologies defined by their functional usage in information access. As pointed out by Capron (2000), mails, telephone, TV and radio, books, newspapers and periodicals are the traditional ways users send and receive information. By using IT, learners/users can access myriads of information with less time.

Information Technology (IT) policy is a plan of action that guides decision and action as well as political, management, financial and administrative mechanism/arrangement to reach explicit goal. IT policy formulation usually involves coming together of individuals, professional bodies, institutions of higher learning, co-operate organizations that are concerned with IT, since it involves brainstorming and collaboration among IT shareholders. This approach of generating IT policy is usually tedious and time consuming leading to loss of interest by the participants, and also often lay emphasis on the pressing issues at that particular time. Any issues not discussed here will wait until there is a need for them to review the policy after some years. According to Anderson (1975), policy can be defined as a purposive course of action followed by an actor or set of actors. Various institutions, agencies and governments often maintain their independent policies suited to their objectives. In developing countries, governments may also adopt a range of policies aimed at supporting economic development, such as domestic monetary policy, industrial policy, agricultural policy, trade policy, IT policy, etc. Thus, IT policy is a plan of action that guides decisions and actions on IT resources, as well as political, management, financial, and administrative mechanisms arranged to reach explicit goals.

2. Overview of Previous Works

Government policy failure is more frequent nowadays than it used to be, it seem more precarious for those who are responsible. Policy outcomes have become very difficult to predict as a result of developments in society at large and in the political realm in particular. Government authority is increasingly challenged, traditional policy instruments (legislation, financial incentives) have lost much of their power, and policy making has to take a steadily growing number of complex policy networks into account. As a result of this prediction problem, many policy measures fail to produce the goals set in advance or produce undesired outcomes, or both. The problem of prediction is still aggravated by government's high ambitions (welfare of citizen, safeguarding economic growth, etc.) and by the increase of political interdependencies.

According to Corkery (2006), decisions on policy are taken by the government which in turn is accountable to the electorates. In a modern democracy, the electorates are generally not satisfied with being consulted once every four or five years. People in all countries are becoming more educated and much better informed. Increasingly, they are better able to articulate their needs and have the confidence to put them together in this as relevant interest group if they are to produce the most effective policies. Quinn (1978) offers an ideal approach to this problem which he calls "formal systems planning approach". The approach includes such steps as analyzing internal situation, projecting current needs and resourced in the future. This will facilitate the analyses of opportunities and possible threats as well as identifying the gap between the expected and desired results, communicating planning assumptions, requesting plans for specific goals, needs, and actions. To achieve this, occasional, special studies of alternatives, contingencies or longer-term opportunities will be necessary.

Mayntz (1976) comments that decision making in organizations often involves several actors, which means that processes of exercising influence in interactive situations must be studied rather than individuals' cognitions. She also emphasizes that the distinction made in the 'rational model' between goals and means - a distinction that is often supposed to be connected with different hierarchical levels - does not exist in reality. In contrast, Sabatier and Zafonte (1995) assumed value conflict to exist between 'advocacy coalitions' that involve actors from multiple government levels and agencies as well as interest group members and researchers. Both proposals, whether suggesting 'just' dialogue or no less than a professional/scientific forum as a way to arrive at consensus, assume that organizations and organizational networks (private and public alike) are fields of tension, as a result of the different perceptions and problem definitions held and the different judgment made by the various (interest) groups or stakeholders involved.

Policy-makers may view knowledge as being a set of best practices, often as derived from practical experience (Booth et al. 1988). Lindquist (2001) contends that instances of policy changes may be viewed as being routine, incremental, fundamental or emergent. Routine changes involve minor modifications to existing programs to adapt to new situations, and often involve limited debate. Incremental changes however occur when isolated issues are discussed and reviewed, without an attempt for a comprehensive review of existing policies. We argue that minor trade policy changes such as the imposition of import prohibitions, and the granting of occasional duty waivers, may be classified as either routine or incremental. For such changes, the overarching policy framework remains intact, with changes only being made on the margin. Grindle and Thomas (1991) observed that the linear, the incrementalist and the interactive models policy formulation are often identified. In the linear model, policy formulation is viewed to occur as a logical, technocratic sequence comprised of agenda-setting, decision-making, adoption, implementation and evaluation. The incrementalist model modifies this view, and argues that policy-makers embark on policy changes by making small, marginal changes to existing policies. In this regard, policies evolve slowly, rather than changing in drastic steps.

As noted by Sutton (1999), the incrementalist approach may be valid only in instances of policy reform and appears to be inapplicable in cases when policies are being developed. Finally, in the interactive model, the focus is on the role of policy elites tasked with the actual implementation policy changes (Grindle and Thomas, 1990). The model presents the policy process in a political economy framework, where various actors, who are likely to benefit or lose from a policy change, seek to influence the final outcomes of implementation. According to Kingdon (1984), the policy process consists of multiple streams, comprised of problems, solutions and politics. A policy change occurs when a problem stream, is adequately addressed by a solution stream, in a politically favourable environment. The actual process of policy formulation is also contested at various stages, with a variety of analytical frameworks available to explain the policy process in different contexts.

Bhatnagar (2002) noted that "Most of the national IT policy statements in developing countries seem to be preoccupied with growing IT sector. The vendor community drives the policies. There is very little emphasis on deployment of IT for enhancing the competitiveness of industry or improving governance in these countries. One wonders if any country would be able to emulate the example of India in growing its IT sector. The policies need to recognize the potential impact of using IT on employment and competitiveness, within the enterprise and the government sectors and outline programs to promote such deployment

Expert system is highly domain specific and restrictive, meaning that it is used only to solve specialized problems. An expert system, known as a decision support system, is a computer program that contains some of the subject-specific knowledge of one or more human experts. It is a system that utilizes what appears to be reasoning capabilities to reach conclusion. An expert system as described by Lewis (1986) is noteworthy because it pioneered the use of a linked list for all rules dependent on a given antecedent as well as a list of all rules contributing to a given consequent. Lesser et al. (1988) observed that the reasoning approach or meta-reasoning may elect several approximations: (1) approximate search strategies explore a smaller portion of the search space than would be the case during normal processing, (2) data approximations provide an abstract view of data resulting in a simpler space being searched and (3) knowledge approximations simplify the knowledge being applied in the system so that the search space can be explored quickly. However**,** Decker et al. (1990), declared that coping with these approximations requires a number of new knowledge representations, e.g., filters to eliminate unprofitable hypotheses and strategies.

3. Methodology of the Research

The policy generation processes were studied using purposeful interview technique. Five people who had actively participated in policy review and formulation at national level were interviewed. The different input and output of each of the decision stages as well as their interactions were analyzed using Hierarchical Input Process Output (HIPO) techniques. Decision support system was designed using Unified Modeling Language (UML). The elicited knowledge was represented using rule-based technique. The system was implemented using Prolog programming language. Finally, the system was evaluated by comparing expert decision with the system output.

3.1 Hierarchical Input Process Output (HIPO) Model

The model results from the application of a decision tool called the Analytical Hierarchical Process (AHP). The AHP is a multi-criteria decision-making approach introduced by Saaty (1980). It is a subjective model used to analyze quantitative criteria for the purpose of generating weights of importance of the decision criteria and relative performance measures of the alternatives in terms of each individual decision criteria. The Analytical Hierarchical Process (AHP) is a systematic method developed for comparing a list of objectives or alternatives. AHP is a powerful and flexible decision-making tool for complex, multi-criteria problems in which both quantitative and qualitative aspect of a problem need to be incorporated. It helps decision-makers to organize the important components of a problem into hierarchical structure.

A major strength of the AHP is the pairwise comparison in which the influence of elements of a particular level over those of a lower level is measured. AHP is best applied in a situation where structuring, measurement, and/or synthesis are required. Additionally, AHP can also be applied to a group of decision where judgments made by all the individuals in a group are combined. Some areas in which the AHP has been successfully employed include resources allocation, forecasting, total quality management, business process re-engineering, quality function deployment, etc. The process was represented in form of a hierarchical diagram as shown in figure 1.

At **Level 1** in the figure 1 above, the intention is to identify the most efficient policy. In order to achieve this intention, input is required, i.e. **(Level 2)** which is “Sourcing for Evidence”. Sourcing for Evidence is the aspects of knowledge gathering, research for idea/interest,etc. where Information Technology Policy can be used for planning, managing development change and for achieving sustainable growth. From these criteria, the secondary criteria **(Level 3)**, i.e. “Using the Evidence” is the interpreting, application and utilization of knowledge for policy formulation for sustainable development. This introduces objectives to achieve from different needs of each sectorial application. The lists of sub-criteria

(Level 4) are the actual strategy/strategies to be applied to achieve the objectives. This will invariably lead to achieving an informed decision on the intended sectorial applications and/or mission statement. The alternatives **(Level 5)** are the alternative policy idea.

3.2 System Design

The system designed can be invoked by clicking on the system name, that is, policy formulation. The system comes out with a window that contains introductory message which says welcome to information technology policy formulation menu. Here, there is a dialog box that will ask whether user want to formulate policy, if the response is yes, system displays another screen that contain Vision Statement, Mission Statement, Sectorial Application and Exit. The user can now choose from these options. Each of these has their objective(s) and the strategies to achieve them.

The system designed is analyzed in figures 2 to 4. Figures 2 and 3 demonstrate the use case for the Mission Statement and Sectorial Application respectively. These show the interaction between the user and different modules of the programme. Figure 4 is the Sequence Diagram that explains the sequence of the activities being performed by the user.

3.3 *System Architecture*

Figure 5 shows the architectural model of the proposed system. The human agent or the user has the ability to work towards achieving Mission Statement, Vision Statement. Sectorial Application and System Implementation. The user submits the request to the system. The system verifies the authenticity of the user before the request is granted. If the request is granted, then the system will request from database the submitted request from the user. Using inference engine the database will supply the system the appropriate request i.e. vision statement mission statement sectorial application. The interaction of the system with the agent will produce the output as shown in the diagram (figure 5).

4. Result and Discussions

In this section, the performance analysis of the existing manual policy formulation and the proposed decision support system for policy formulation using Prolog are presented. In carrying out the performance comparison, the following metrics were used. (1) Processing Time Efficiency; (2) Cost Effectiveness of the model

4.1*Processing Time Efficiency*

In measuring the efficiency of the proposed system, the evaluation job processing duration were used as a performance metric. This was done by comparing the processing time of automated system with the processing time it will take human experts to process the same job.

Assuming the average human processing time, (P_{th},) of manually formulated policy is defined as the time it takes the experts to travel from their base locations to the policy formulation centres (C_t), plus the time it takes to look for experts (T_t), plus the time to make the necessary brainstorming to arrive at the best opinion (A_t). This gives the following equation for the average human expert processing time:

$$P_{th} = C_t + T_t + A_t \qquad \ldots\ldots\ldots (1)$$

where journey time, C_t, can be deduced from the general equation of motion in physical sciences:

i.e; C_t = Total Distance/Speed(s)

= Distance (d) /Speed(s)

= (d/s)

Where distance, d, is the distance between the experts' locations and the policy formulation centre and average speed is given by the speed of the experts with his car. Therefore, the real processing time for the manually formulated policy is

$$P_{th} = (d \div s) + T_t + A_t \qquad \ldots\ldots\ldots (2)$$

Let the average processing time for Expert System be P_{te}. This can be defined as the time it takes the user to interact with the computer (t_1), plus the time it takes the computer to extract the required data for the solution from the database (t_2), plus the time it takes computer to display the result (t_3). This is given by:

$$P_{te} = t_1 + t_2 + t_3 \qquad \text{...} \quad (3)$$

The simulation result shown in table 1 and figure 6 shows that the appraisal job processing time using the automated solution is better than the manual policy formulation process currently being used. The processing time for formulation of policy by human experts takes months, even years in some cases for completion, while this takes milliseconds on digital computer.

Figure 6, shows this simulation graph and Table 1 shows the corresponding data from the simulation program. In Table 1, TD = Total Distance, Ass = Average Speed, C_tH = C_tHours,

T_tH= T_tHours, A_tH= A_tHours, $P_{th}H$ = P_{th}Hours, $P_{th}M$ = P_{th}Minutes, $P_{th}S$ = P_{th}Seconds, A_uM = Automatedinseconds. The Average speed used, was obtained from Federal Road Safety Commission of Nigeria as a standard speed.

4.2 *Cost Effectiveness*

The cost effectiveness of the proposed system was investigated by comparing it with existing manual ways of policy formulation. Unlike traditional manual method that make use of result on papers based on experience, expert system offers a dynamic result that adapts to changes without human intervention.

In evaluating the course effectiveness of the models (manual and the proposed DSS), the following mathematical model was employed:

Let Domain be denoted by $D_1, D_2, D_3, \ldots\ldots\ldots\ldots, D_n$

Let the total Experts in each domain be denoted by; $E_1, E_2, E_3, \ldots\ldots\ldots\ldots, E_n$, where

$E_1 = a_1 + a_2 + a_3 + \ldots\ldots + a_n$, $E_2 = b_1 + b_2 + b_3 + \ldots\ldots + b_n$, $E_3 = c_1 + c_2 + c_3 + \ldots\ldots + c_n$, etc.

Let the Cost of hiring experts in each domain be denoted by $C_1, C_2, C_3, \ldots\ldots, C_n$, where

$C_1 = k_1 + k_2 + k_3 + \ldots\ldots + k_n$, $C_2 = l_1 + l_2 + l_3 + \ldots\ldots + l_n$, $C_3 = m_1 + m_2 + m_3 + \ldots\ldots + m_n$, etc.

Therefore; Cost of hiring experts for domain $D_1 = C_1 = k_1 + k_2 + k_3 + \ldots\ldots + k_n$

Cost of hiring experts for domain $D_2 = C_2 = l_1 + l_2 + l_3 + \ldots\ldots + l_n$

Cost of hiring experts for domain $D_3 = C_3 = m_1 + m_2 + m_3 + \ldots\ldots + m_n$, etc.

Therefore; Total Cost of hiring experts in all domain $(T_c) = C_1 + C_2 + C_3 + \ldots\ldots + C_n$

i.e. $T_c = \sum C_t$, where t =1 to n (n = total number of domains).

From the simulation result data in Table 2, the cost of manually processing activities of policy formulation remains consistently higher than the cost that would be incurred if automated solution was used. The reason for this is that, in the manual process high service /operating costs is involved as human experts has to incur the cost of transportation, accommodation and feeding during the period of research for knowledge and policy formulation while only the cost of using comparable resources of automated system is charged for the computerised model. Figure 7 shows the graph of cost incurred by using manual method against the automated system. Manual Process Total cost represents the cost of manual process, while Automated Process Total cost represents the cost of automated process.

5. Implementation and Performance Evaluation

In figure 6, five major cities in Nigeria were considered for the model. The cities are Abuja, Enugu, Kaduna, Lagos and Port-Harcourt. Abuja being the federal capital was used as policy formulation centre. The road distance TDS between each city and Abuja was used to determine the distance in kilometres, therefore 595, 180, 793 and 830kms are road distance between Abuja and Enugu, Kaduna, Lagos, Port-Harcourt respectively. The average speed ASS of 100 kilometres per hour (collected from federal road safety commission of Nigeria (FRSCN)) was considered reasonable for a car when embarking on road journey

The time 0.0, 5.95, 1.80, 7.93 and 8.30hrs are the time (CtH) required to travel from Abuja, Enugu, Kaduna, Lagos and Port-Harcourt respectively to the policy formulation centre. The time 24, 48, 48, 48 and 48hrs are the time (TtH) required to search for experts in Abuja, Enugu, Kaduna, Lagos and Port-Harcourt respectively. The time 24, 24, 24, 24, 24hrs are the time (AtH) used by hired experts for brainstorming before arriving at the best opinion value in each city. The time (PthH) is the summation of CtH, TtH, AtH for each location as discussed in equation 1. The time is measure in hour. This is the processing time for manual processing in each location. PthM and PthS are obtained by conversion of PthH to minutes and seconds respectively. The last column of table 1 is the average processing time for automated system (AuM) in seconds.

In figure 7 cost of hiring expert for domain D1, D2, D3, D4 and D5 are 750, 850, 400, 600, 1000 thousands of naira respectively. The cost was based on the requirements for each domain; since the operating cost of automated system will be constant irrespective of the domain.

6. Conclusion

Information has always played key role in the life of mankind from the time of early man. However, in the mid-twentieth century, the role of information increased tremendously as a result of social progress and the vigorous development in science and technology. The pace of change brought by new technologies has had a significant effect on the way people live, work, and play worldwide. In this work, a decision support system for Information Technology policy formulation has been developed and evaluated against the manual method. The methodology used involved obtaining information through purposeful interview of professionals and experts in the field of IT policy formulation, who had participated in the policy review and formulation at national level. Furthermore, information in the context of the policy was also obtained from literatures while the knowledge obtained was represented, using rule based techniques. This technique is used because of its flexibility and at the same time it relates some known information to other information that can be concluded or inferred to be known.

The design of each of the stages involved in the policy document and interaction involved in each of the process with the system is analysed. Hierarchical Input Process Output (HIPO) was used to analyse various input and output of the system. The model results from the application of a decision tool called the Analytical Hierarchical Process (AHP) which is a multi-criterion for the purpose of generating weights of importance of the decision criteria and relative performance measures of the alternatives in terms of each individual decision criteria. The result obtained from interviewing experts in the field of information technology was used to develop the system using prolog software. The system is to guide the decision makers in the development of IT based policy documents. It will also eliminate some problems usually encountered during policy formulation.

The metrics used for evaluating the system are processing time and cost effectiveness. Considering the processing time and efficiency, the result of simulation shows that for policy formulation process, the manual system requires 172800, 280620, 265680, 287748, 289080s for Abuja, Enugu,, Kaduna, Lagos and Port-Harcourt respectively, while the developed DSS requires 0.5435, 0.5185, 0.4905, 0.5308, 0.550s for Abuja, Enugu,, Kaduna, Lagos and Port-Harcourt respectively. The result also shows that the manual process of (IT) policy formulation is very expensive, because the cost of bringing experts from various domains together varies with distance whereas in the case of the automated system, the cost of a complete computer system is constant irrespective of the city.

In conclusion, the result when compared with manual method of policy formulation shows that the automated way of policy formulation is cost effective, efficient, consistency and reduces job processing time with high quality of result. This therefore makes the automated system to be preferable to the manual method of policy formulation.

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Table 1: Simulation data for manual processing versus automated processing time

Cities	**TDs**	**Ass**	**C_tH**	**T_tH**	**A_tH**	**$P_{th}H$**	**$P_{th}M$**	**$P_{th}S$**	**A_uM**
Abuja	0	0	0.00	24	24	48.00	2880.0	172800	0.5434

Enugu	595	100	5.95	48	24	77.95	4677.0	280620	0.5185
Kaduna	180	100	1.80	48	24	73.80	4428.0	265680	0.4985
Lagos	793	100	7.93	48	24	79.93	4795.8	287748	0.5308
Pcourt	830	100	8.30	48	24	80.30	4818.0	289080	0.5500

Table 2: Simulation data for cost effectiveness of manual versus automated process

	Total Cost C('000)	
Domain	**Manual Process**	**Automated Process**
D1	750	300
D2	650	300
D3	400	300
D4	600	300
D5	1000	300

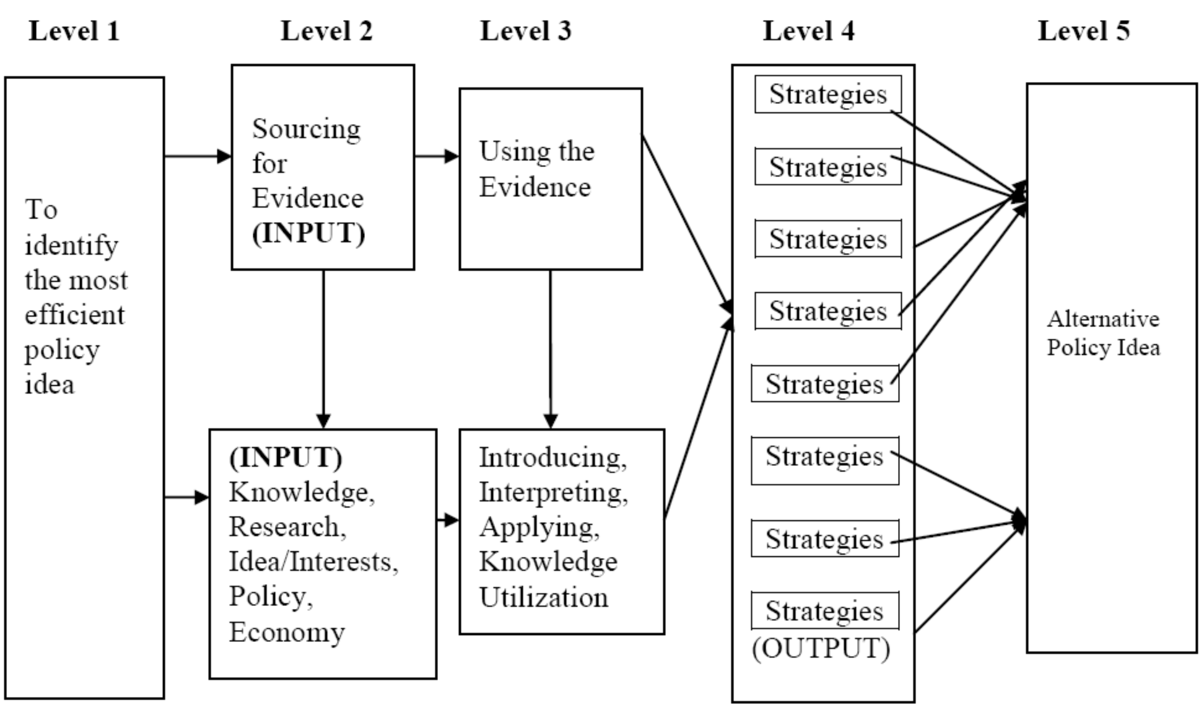

Figure1: Hierarchical Input Process Output Diagram of the System

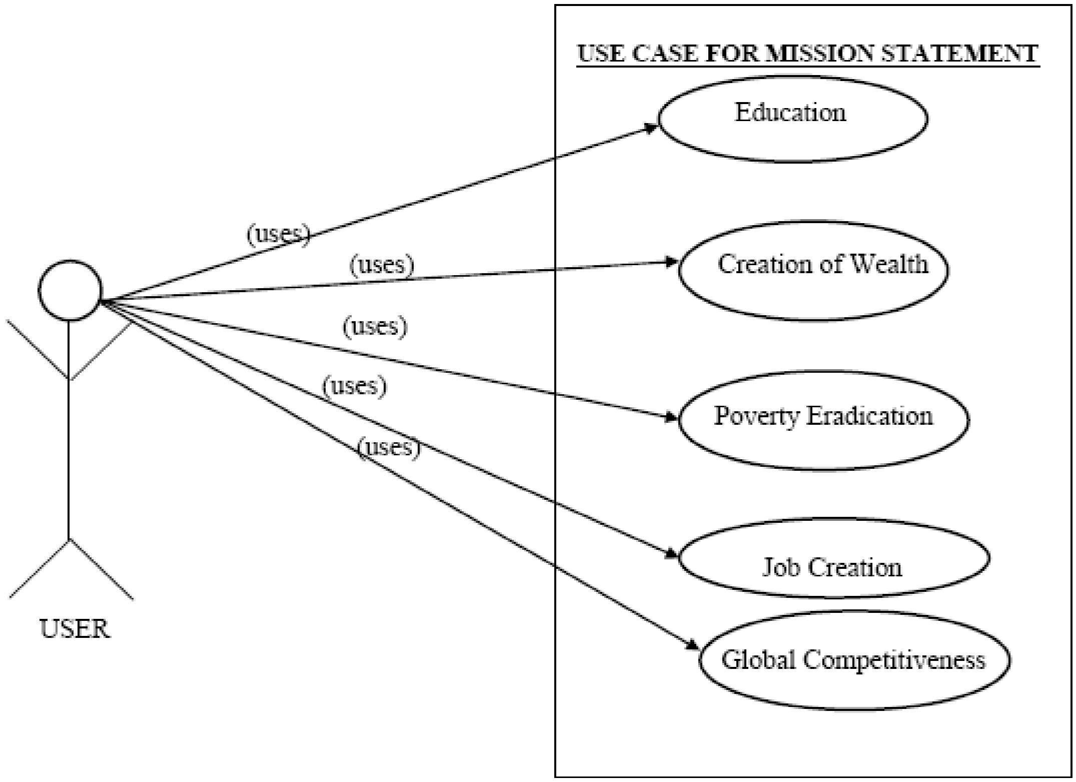

Figure 2: Use case for Mission Statement

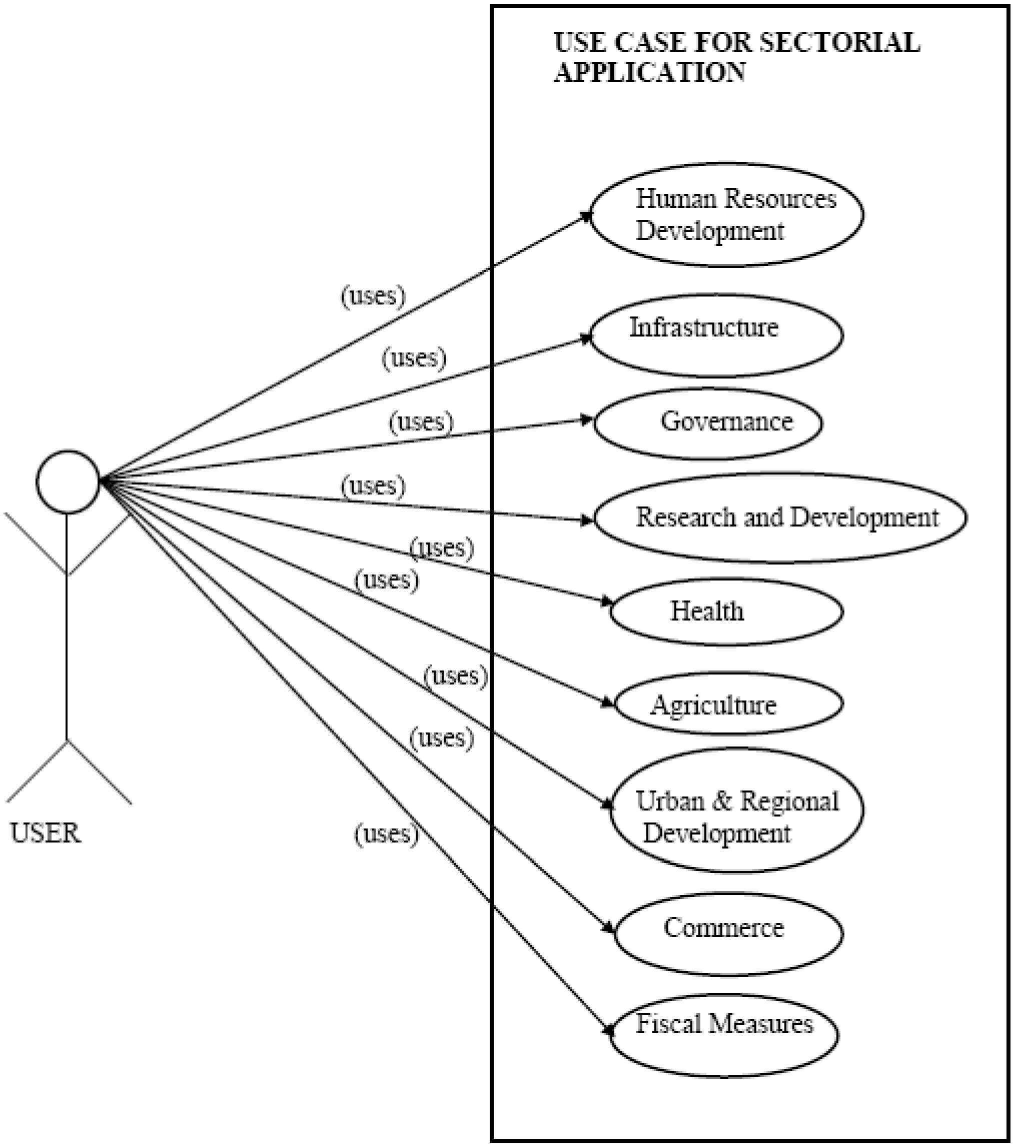

Figure 3: Use Case for Sectorial Application

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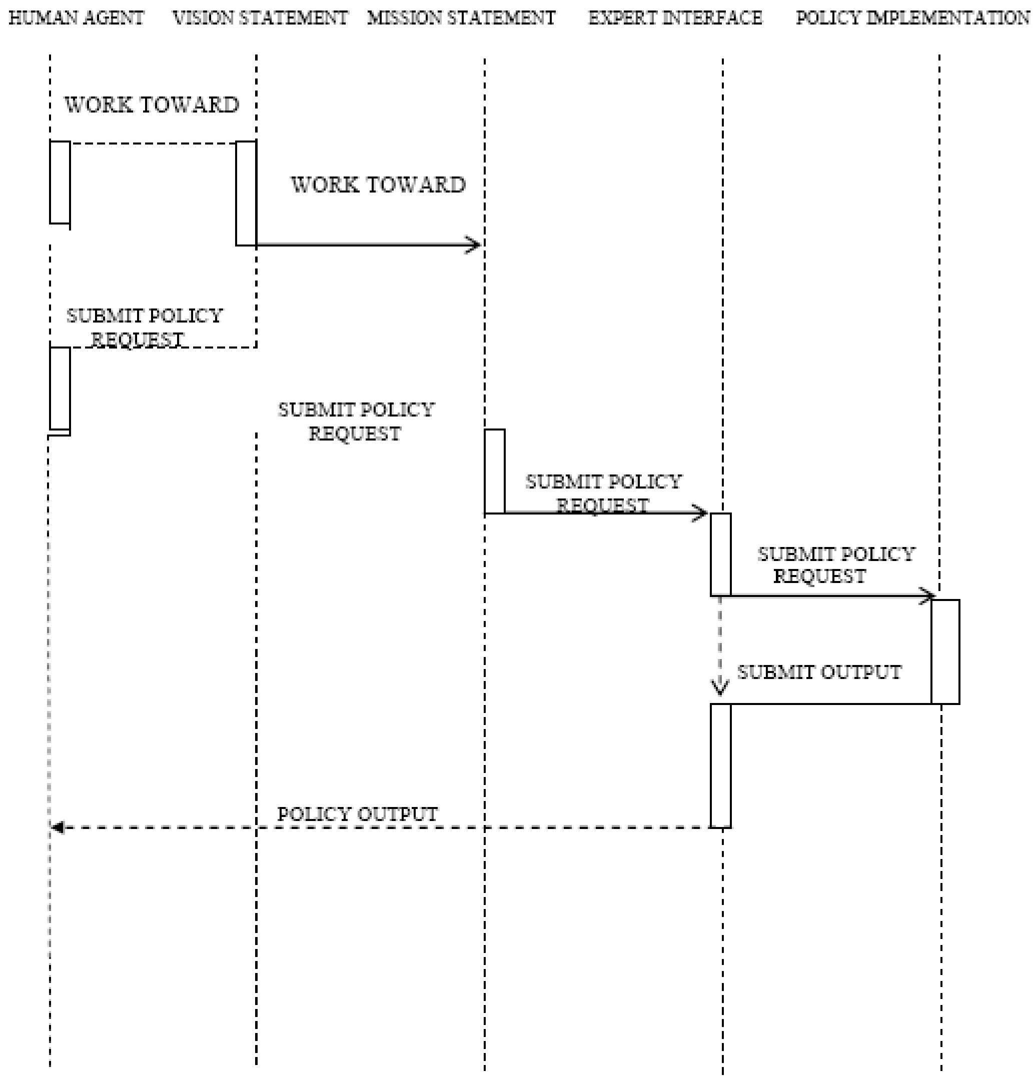

Figure 4: Sequence Diagram of the System

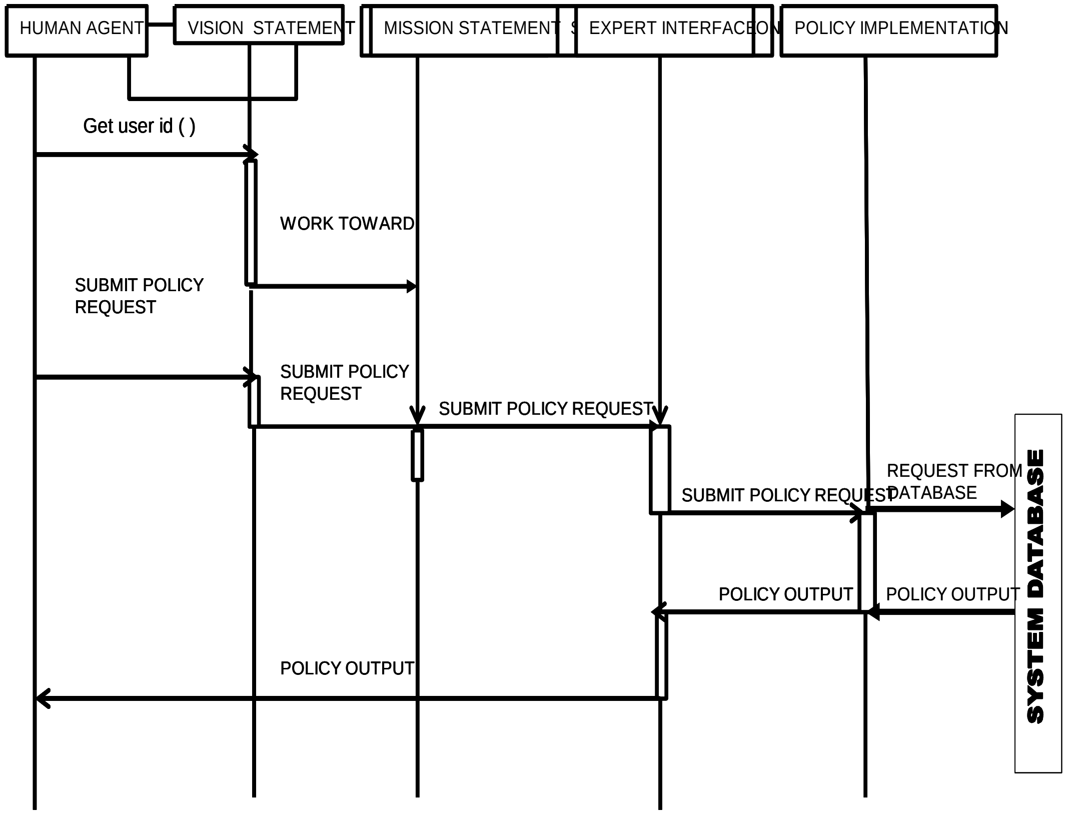

Figure 5: Architectural Model of the System.

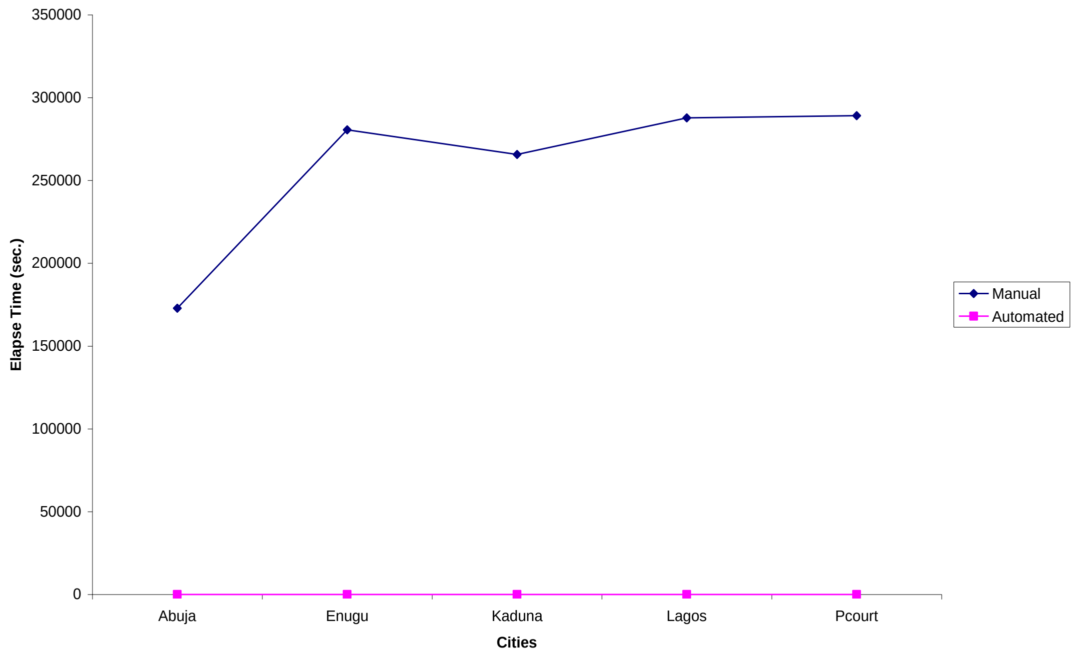

Figure 6: Simulation results of job processing time for manual and automated system process per cities.

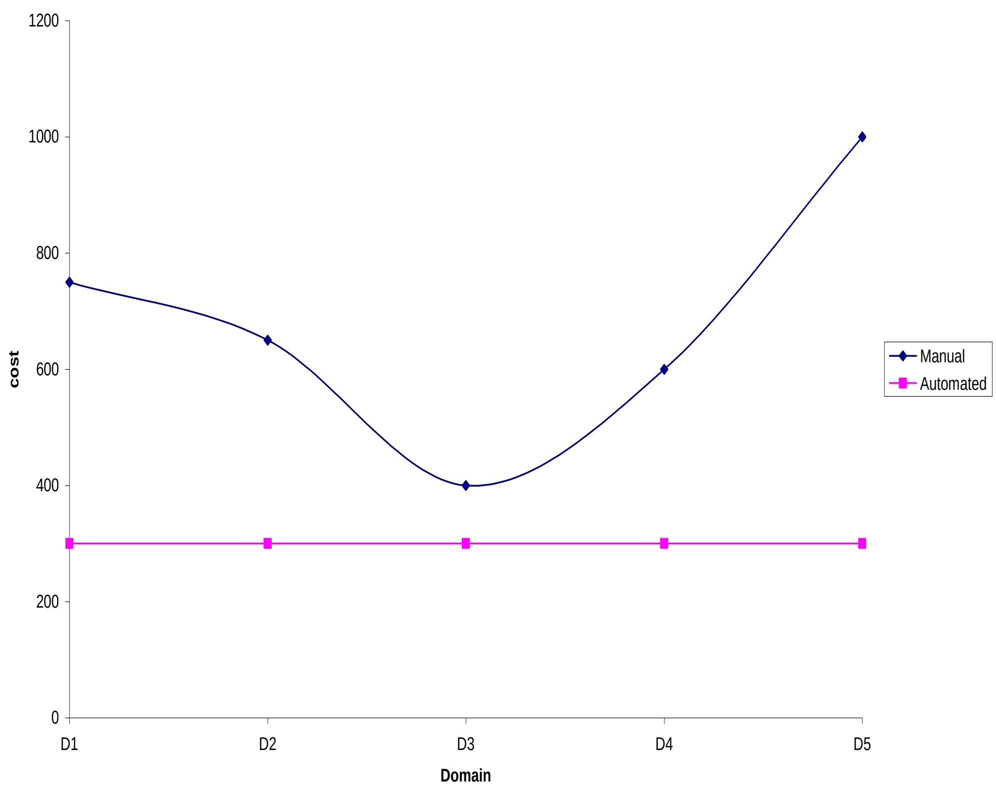

Figure 7: Simulation results of cost effectiveness of manual and automated process of policy formulation