# Modelling income poverty in the Geographic Targeting Geo-Information System

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**SUMMARY**

*Halving world extreme poverty by year 2015 has been made the first and most prominent of the 8 United Nations' Millennium Development Goals (MDG) thus making the issue of poverty reduction a global challenge. Harnessing the potential of GIS-based ICTs for poverty reduction is imperative. As spatial determinants are being considered essential in understanding poverty, there is an increasing use of GIS in handling poverty. However, the use of GIS is raising fundamental and methodological issues in relation to the spatial modelling of poverty and the limitations of GIS as a tool for use in all aspects of poverty reduction. In modelling poverty assessment, for instance, GIS software has no functionality for Econometric and Anthropometric measurement of poverty. Hence, the need to extend GIS functionalities. This paper describes the modelling of income poverty, within the framework of the Geographic Targeting Geo-Information System (GTGIS) for poverty management. Income poverty is modelled as a part of the Poverty Assessment Module, which is based on object-oriented technology. Using a Rapid Application Development approach, the Unified Modelling Language (UML) is used for system design.*

**KEYWORDS:** *Modelling, UML, income poverty, poverty reduction programme*

## INTRODUCTION

The United Nations' Millennium Development Goal (MDG) of halving the 1.2 billion people living in extreme poverty by year 2015 attests to the fact that poverty has become a global issue. Although it is already five years after the setting of the MDG, not all regions of the world are on track to achieving the poverty goal. While poor people are found in all parts of the world, the largest numbers live in South Asia (135 to 190 million). The highest incidence is in sub-Saharan Africa (SSA), where thirty to forty percent (30–40%) of all extremely poor people are trapped in poverty – an estimated 90 to 120 million people (CPRC, 2004). Knowing that the poverty goal will not be met in some regions, especially SSA by the 2015 deadline unless there are new ideas and actions, the development of Information and Communication Technology (database systems GIS inclusive), and early warning systems for different applications feature as priority areas on both regional and global development agenda. The achievement of this international poverty goal will require concerted effort, both in research and in the practice of poverty reduction. Beyond global initiatives, analysis of poverty at the micro (local) level is imperative as various central government activities in many developing countries are being decentralised to local levels. Information on micro-level poverty are needed by local administrations and communities to aid policy-making and empowerment of marginalised groups.

Realising the need to reduce poverty, many developing countries have initiated poverty reduction programmes (PRPs). The geographic blindness of many of these programmes is their main weakness as the spatial dimension of poverty are not taking into account in both their design and implementation. These programmes exhibit a weak link, theoretically and practically, between poverty and geographic location although this indisputable link have been established by emerging studies. Moreover, there is interrelationship between social processes and many other phenomena such as environmental, political and cultural variables across geographic space. Bigman and Fofack (2000) noted that:

> In recent years the ability to incorporate geographic indicators in public policy planning in general, and in the design of welfare programs in particular, took a quantum leap with the development of new and sophisticated methods for incorporating spatial data and organizing these data as a GIS suitable for computer analysis….By including in the GIS database not only information on social, economic, climatic, and environmental observations, but also their location and spatial arrangement, this system allows us to present the data in the form of maps and interfaces and to perform comprehensive and sophisticated spatial analysis. In many countries (developing and industrial) this system has become the single most important tool for analyzing a wide range of geographic and socioeconomic data and for designing policy measures.

Consequent upon the use of GIS in handling poverty and other social problems, researches on spatial modelling are urgently required to aid the appropriate modelling of social processes and enhancement of GIS functionalities. Such research efforts have social relevance and could emerge as one of the greatest contributions to be made by the Spatial sciences to poverty reduction and its related problems globally.

## MODELLING POVERTY

Poverty analysis has gained increased currency as an input into policy-making. Meanwhile, the very meaning of poverty remains the subject of debate, and differences of opinion persist on how best to handle poverty (Hentschel and Lanjouw, 1996). To start with, poverty definition and measurements vary from country to country because of their specific characteristics and differences in cultural values. A critical examination of poverty connotes an unacceptable deprivation in human well being that comprises of low monetary income and consumption levels as well as lack of basic human capabilities: illiteracy, malnutrition, abbreviated life span, poor health, illness from preventable diseases and social deprivation such as risk and vulnerability. Poverty is broadly categorised into Income and Human poverty, for which Econometric and Anthropometric based poverty indices are used respectively. Focus within this paper is limited to modelling income poverty at a micro-level, where money income, is the only relevant variable of interest in computing poverty indices.

### Spatial modelling of poverty

It is to be noted that social processes generally are not as amenable to spatial analysis as natural and environmental processes. This is mainly due to the complex, multifaceted, and ill-structured nature of most social problems, especially poverty. The problem of poverty is related to food-insecurity, ill-health, illiteracy, unemployment, gender based problem amongst others. Poverty levels vary between and within countries, regions or other geographic and administrative units. As a matter of fact, the manifestations of poverty in different parts of the world are as a result of the interplay of myriads of factors (agro-ecological, socio-cultural, economic and political factors) over time and they all vary over geographic space. Consequently, the spatial modeling of poverty raises methodological questions related to how best can the required picture of poverty as a whole be derived? 'Is it through the use of separate models that could help capture important aspects of each poverty facet, which can then be reassemble'? or 'is it through the use of an all-encompassing model that captures all facets'? As an aid to the abstraction process, spatial modelling of poverty could be done in a much simpler way by splitting up poverty into its numerous facets and simultaneously identifying areas of overlap between these facets since they are generally not mutually exclusive. The non-recognition of the multifaceted nature of poverty accounts for the failure of many poverty reduction initiatives, which often only succeed in handling segments of the overall poverty problem. Of a truth, each of these facets possesses some distinguishing characteristics and may require the use of specialized approaches. Sometimes different instruments are designed and used by policy makers to advance different goals, such as increasing school enrolment or lowering child morbidity, rather than following the same general goal of alleviating poverty. Focusing attention only on income poverty as the case is in this paper, helps to zero in on the monetary facet of poverty. This enables the making of inferences and choice decisions about income poverty. Other poverty facets of interest can also undergo this same modelling process, which are then reassembled to give the whole picture. This approach is based on the poverty management (PM) concept, which is an all-encompassing concept that incorporates all aspects of poverty reduction (poverty assessment, poverty alleviation and its monitoring) within a spatial framework using both income and human poverty approaches (Akinyemi, 2003). Detailed discussion on the PM is under the GTGIS section.

## Handling income poverty

How to derive household income is the most critical issue in modelling household income poverty. The use of household head's income for computing household income, fails to capture all income sources accruing to a household as other members of the household may have incomes too. The importance of this fact can be seen from the African poor household scene where, for example, household income sources may include household head's earnings (sometimes such earnings are derived simultaneously from formal and informal occupation), spouse(s) income and remittances from the children (this could be from grown-up children and children's economic activities).

Jenkins (2000) in his study of Britain defined net household income as labour earnings from employment and self employment, returns from savings and investment, returns from private and occupational pensions, all public cash transfers (cash benefits), excluding national income taxes and social security contributions and local taxes charges of not only the household head but other persons in the household. It is necessary to adjust household income to reflect individual needs. This can be done by applying an equivalence scale factor. In this study, household per capita income (PCI) is used instead of total household income, by dividing household income simply by the number of persons in the household. A setback of using the PCI is that it shares household income equally among members irrespective of household compositional characteristics (age, sex etc.).

It may become necessary to examine the impact of poverty reduction policies on poverty levels over time. This makes the study of household poverty dynamics imperative, which is simply transitions above or below some low income cut-off (movements between discrete states; Jenkins, 2000) over time. To describe household poverty dynamics, mainly, three kinds of models are in use in literature. These are the hazard regression models of poverty exit rates and re-entry rates, covariance structure models which fit a stochastic time-series structure to income, from which the implications for poverty are derived, and a first order Markovian model of poverty transitions which models the initial poverty status and non-random attrition in addition to poverty transition (Jenkins, 2000).

## GIS use for income poverty assessment

The selection tool in GIS is commonly used whereby a query is applied that selects households whose income or consumption (per capita) lie below a set poverty line. The result is to visualize the spatial distribution of poor households, for example, by simply distinguishing between poor and non-poor households in a sample area. Its versatile database capability is utilized to integrate socio-economic data from censuses, household surveys, which are often crossed with geographic data for community selection refinement in the process of targeting beneficiaries. Its analytical functionalities are invaluable for making poverty maps. Sometimes queries are applied that uses the features of a layer (e.g education) to choose features in another layer (e.g poverty levels). This is a demonstration of GIS capability to find answers that will help in decision making using spatial relationships. With data fixed to specific locations within a common spatial framework in a GIS, different types of poverty maps can be generated from the results of poverty assessment.

Looking at the example of a project in Malawi that aims at combating hunger and poverty, it is important to know where hungry and impoverished people are concentrated. National estimates of the number of undernourished people or the proportion of the population living on less than USD1 per day provided useful indications of national progress over time. But these could not be used to target specific villages and the conditions that make the inhabitants poverty and hunger prone. With estimates of local poverty, GIS is useful in constructing detailed poverty maps. These maps are combined with other geo-referenced data to highlight areas where hunger and poverty overlap with other social, economic and environmental problems. Maps can be made, for example, to show semi-arid agricultural areas with poor access to roads and high levels of goitre and female illiteracy. This information can then be used to design programmes that address specific local problems (see SOFI, 2003).

This upsurge in the production and use of poverty maps for various applications is recent and this increasing use of GIS in handling poverty also raises fundamental issues. Most issues are related to data requirements and these are well treated in literature. Examples are the unavailability of disaggregated data for micro-level poverty (spatial) analysis, and where available, socio-economic data may not be georeferenced; lack of in-depth understanding of the statistical problems that must be taken into account when using spatial variables; the lack of subnational poverty data that is comparable across countries also hampers the development of global and regional poverty mapping (see Davis and Siano, 2001). Other issues relate to the high level of technical know-how required for GIS usage and system capabilities, such as limitations of GIS as a tool for use in handling all poverty reduction tasks.

### GIS limitations for modelling social processes

The fact that GIS is limited in its use for handling poverty or related processes have been recognised. In response, some areas of need have been identified for which different systems are emerging. Examples of such are systems that support: the analysis of both the spatial and temporal dimensions of regional income growth and convergence (Rey and Janikas, 2004); urban spatial interaction (predictive) models and location-allocation (prescriptive or optimising) models which are linked to GIS. To identify pockets of poverty, an integrated population census database (microcomputer-based software package) was linked to GIS via software-interface (Hall and Conning, 1991). To measure the levels of poverty, they considered the physical conditions of the dwelling units, the services supplied to the units and household income. For public planning, GIS is being linked to modelling and forecasting systems although the development of formal design methods using GIS is an ongoing exercise (Batty and Densham, 1996). GIS is also limited as a tool for use in some aspects of poverty reduction. In carrying out poverty assessment, for instance, functionalities for econometric and anthropometric measurements of poverty are lacking in a typical GIS. As a result, the enhancement of GIS by the extension of its functionalities to carry out the assessment of poverty as well as its alleviation and monitoring becomes necessary.

## THE GEOGRAPHIC TARGETING GEO-INFORMATION SYSTEM

This objective of GIS enhancement forms the basis for the development of the Geographic Targeting Geo-Information System (GTGIS), a Spatial Decision Support System (SDSS) for poverty management in SSA. Conceptually, the GTGIS is based on the Poverty Management concept using a modular structure. It comprises of poverty assessment, poverty alleviation and poverty monitoring modules. We would proceed to examine each module briefly.

### Poverty assessment module (PAM)

This module is concerned with the assessment of income and human poverty. There are many measures in use, the income measures range from the very simple headcount to the more robust ones like the Foster-Greer-Thorbecke (FGT, 1984) decomposable poverty index and the small area poverty estimation methods. Human poverty measures include but are not limited to measures based on the unsatisfied basic needs approach, human poverty index and human development index. It is well established in literature that these different measures may lead in different directions as regards which units are most appropriate for policy interventions as they tend to give different distributions of poverty (see Davis, 2003). Although the issue of which poverty measure to choose for a particular policy direction is outside our concern in this system, implementing more than one poverty measure in the GTGIS is necessary. Examples of measures included in the system are the FGT index comprising of poverty headcount, the income poverty gap ratio (income gap) and the poverty severity (severity) ratio. The design of the PAM will be discussed in details under the system design section.

### Poverty alleviation module (PALM)

The design of PRPs are based on assessed poverty levels and the clear understanding of the interplay between socio-economic, demographic and geographic factors that make households at risk of poverty. With the increasing need to target poverty programmes mainly as a result of dwindling revenue, geographic targeting techniques are being used. This module is meant to model the poverty alleviation process, in order to assist poverty managers in using geographic targeting in relation to taking decisions as to where social interventions are most needed.

### Poverty monitoring module (PMM)

This module is concerned with the modelling of household poverty dynamics. There is often the need to judge the effect of poverty reduction policies over time, or to estimate the impact of a PRP on poverty. Such needs show the necessity of spatio-temporal modelling of household poverty in the GTGIS, although this time component increases the complexity of the system. Although the modeling of household poverty dynamics is beyond the scope of this paper, functions with which to calculate poverty lines for legitimate comparisons of poverty rates between locations over time are included in the PAM. In the absence of poverty lines that reflect local standards of living, it becomes necessary to derive absolute poverty lines for use in studying micro-level poverty dynamics and for comparing locations over time. Between countries the absolute poverty lines of USD1 (extreme poverty) and USD2 per day (moderate poverty) are used for income poverty comparisons, however these international poverty lines are inappropriate for micro-level poverty analysis.

## SYSTEM DESIGN

For system design and development, the iterative and incremental software development model is adopted. This model is "…based on the successive enlargement and refinement of a system through multiple iterations, with cyclic feedback and adaptation as core drivers to converge upon a suitable system. The system grows incrementally over time, iteration by iteration" (Larman, 2002). Each iteration would consist of the user requirements analysis, design, implementation and testing stages. This model is adapted to the Rapid Application Development (RAD) method for GIS application development, which allows the quick setup of the system (Hu, 2004). The RAD ensures high flexibility and continuous design refinement and enhancement during the software development process. Currently, the GTGIS is at the design stage with the Unified Modelling Language (UML) used for system modelling. For system design and analysis, the Borland Together 6.2 software is used to create all the UML diagrams based on object-oriented (OO) concept. The system is to be developed within ArcGIS Desktop environment with ArcObjects using Visual Basic for Application.

## Analysis – income assessment modelling and system specification

User requirements gathering and analysis is required at this stage and these is already done through fieldwork in Nigeria and indepth study of poverty in an urban context for a doctoral thesis. Detailed use case diagram is designed to model the income poverty assessment aspect of the PAM and defining dependency relationships between use cases (see Figures 1 and 2).

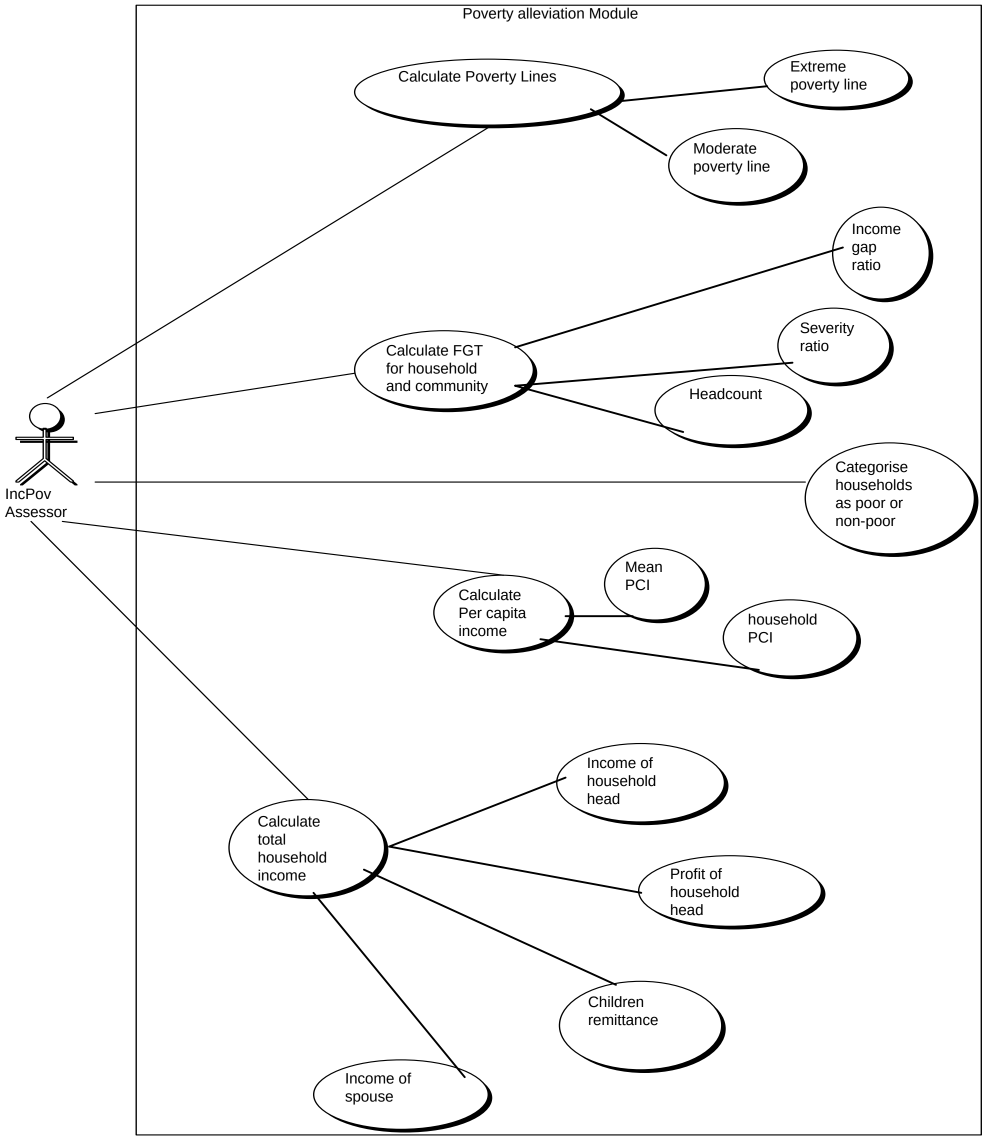
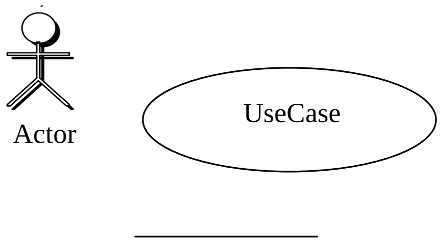



*Figure 1*: The income poverty assessment use diagram

The boundary between users and the system needs also to be defined. All that is within the rectangle represents the system boundary, which is a part of the functionalities defined in the PAM.




Indicates use cases that are included in another use case

*Figure 2*: Legend of use case diagram

The use case model aids in the identification of actors and use cases from a software specification perspective. On the basis of this use case diagram, the functional user requirements for income poverty assessment are identified and described as follows:

- Calculate total household income - this is needed since households tend to have more than one source of income.
- Calculate per capita income (PCI) - household PCI is to be calculated for each household, while the mean PCI is calculated for each community.
- Calculation of poverty lines - extreme poverty line and moderate poverty line are calculated where there is no official poverty line(s).
- Calculate FGT index - All households are categorised into poor and non-poor categories. Except for the headcount, both income gap ratio and severity ratio are calculated at both household and community levels.

### Detailed Class Diagram

With the use of OO concept classes, attributes, data types of all attributes, operations and interfaces were defined. Their identification posed to be the major challenge faced in the design of the PAM. In developing the class diagram, the first thing we needed to do is to identify classes in the PAM as it relates to income poverty assessment (see Figure 3).

The class names and are: Community: defines a level of aggregation which is made up of households. The relationship is such that a community can be made up of 1 or many households; Household: defines a level of aggregation which is made up of persons. The relationship existing between Household and Person is such that a household can be made up of 1 or many persons; Person: defines an individual member of the Household; Income: defines the sources of income that may accrue to a person. The relationship is such that a person can have 1 or many sources of income.

### System Behaviour Modelling

With the use of Interaction diagrams we are able to model how a set of objects collaborate in some behaviour. Looking at the case of calculating the extreme poverty line, objects and the messages that are sent between these objects can be seen in the interaction diagram (See Figure 4).

This interaction diagram describes the Income Poverty Assessor sending a message getName() to object :Community requesting the name of the selected Community. The :Community object again receives a calcExtremePovertyLine() message. The :Community object now sends a message getPCI() to each :Household object in turn in order to build up a list of PCIs to sum up.

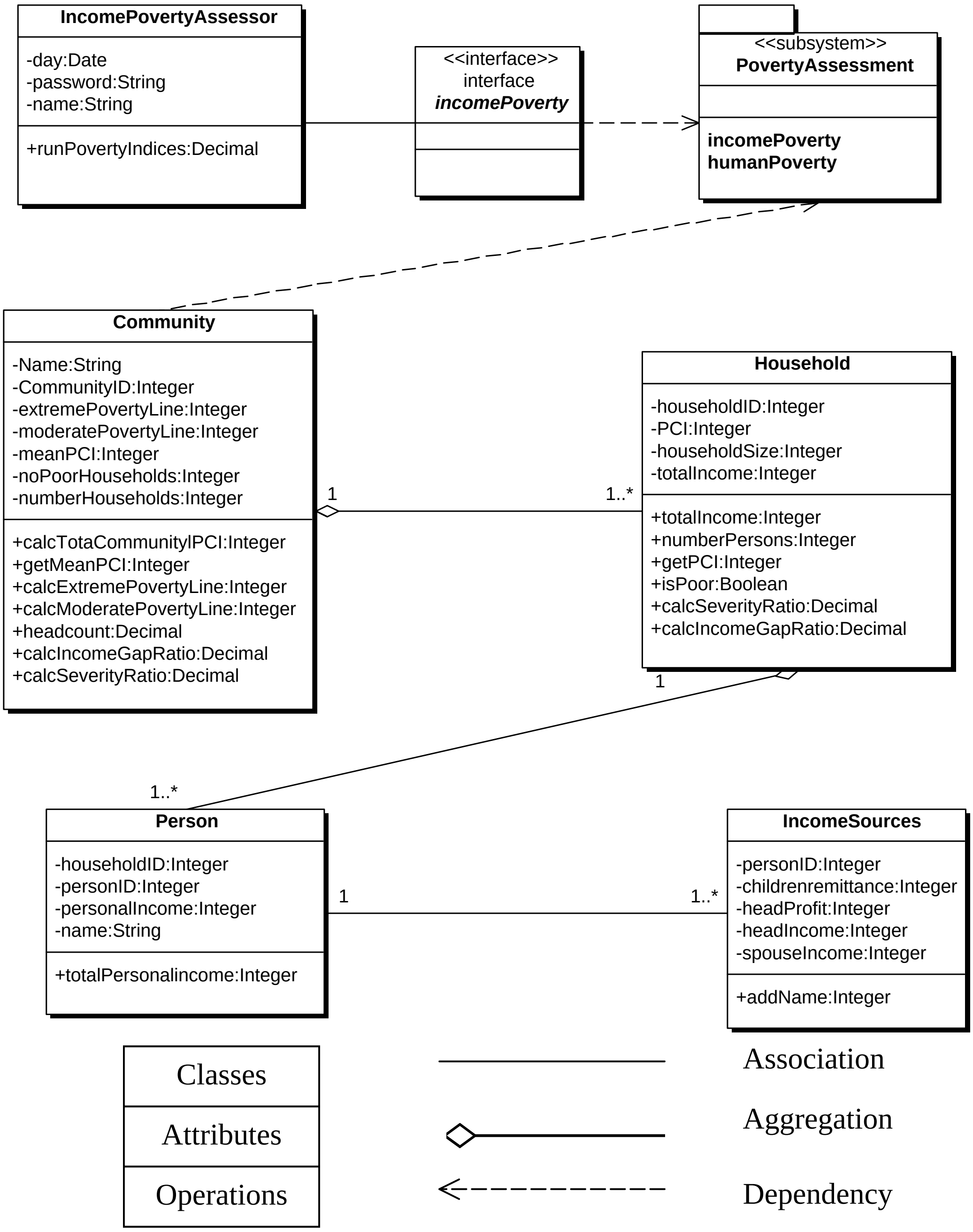



*Figure 3*: The class diagram

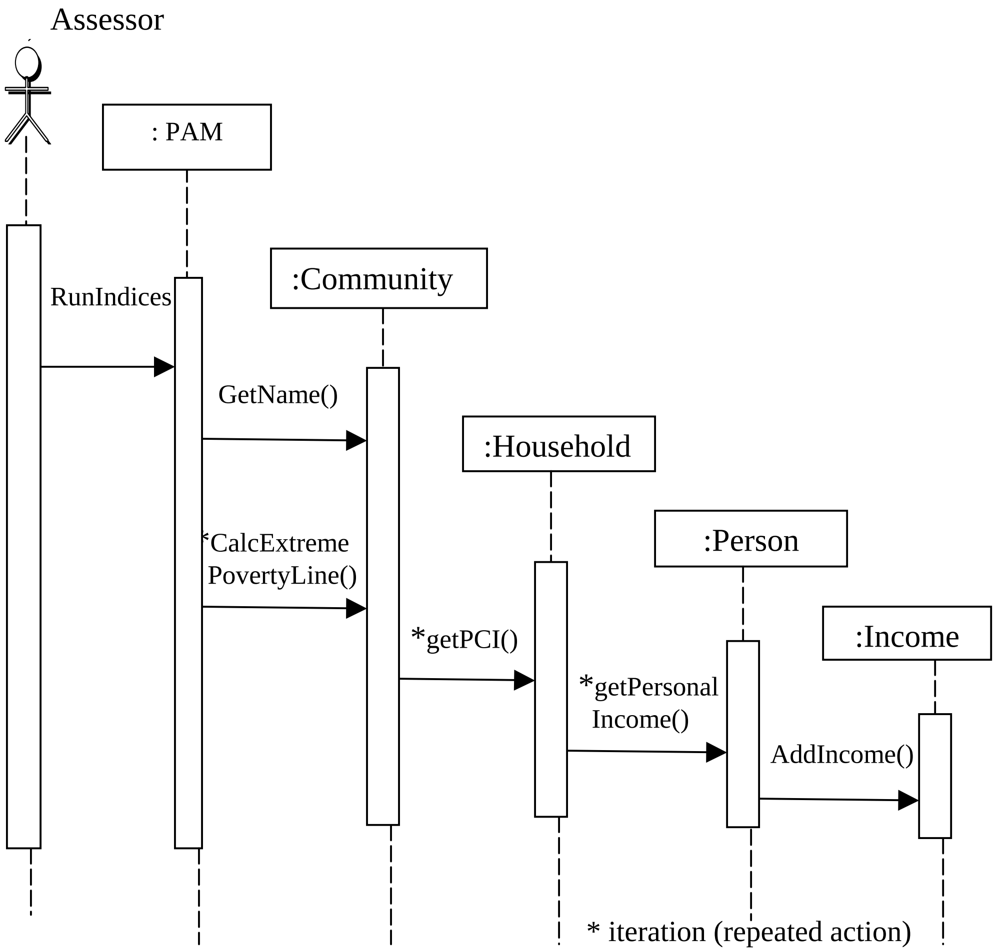



*Figure 4*: Interaction diagram for calculating the extreme poverty line

The :Household object sends a message getIncome() to each :Person object, which in turn sends a messageaddIncome() to :Income object to sum all incomes belonging to a person. The Income Poverty Assessor gets the extreme poverty line after the PAM operation addIncome is successfully executed. It shows clearly the messages passing between these objects. In the same time, it also shows which object takes what responsibility.

## CONCLUSION

The increasing use of GIS in handling poverty and other related problems was discussed. Consequently, there are methodological and system capability related issues that need to be addressed through research. Some of these issues have got to do with the spatial modelling of poverty. In this paper, the modelling of household income poverty was addressed. The need to enhance GIS capability for better handling of poverty reduction tasks led to the discussion on the GTGIS. The identification of classes, their attributes, operations and relationships as well as the general design of income poverty assessment functionalities in the PAM was discussed with the aid of UML diagrams such as use cases, class and interaction diagrams. The development of the GTGIS is an ongoing research, which is presently at the design stage.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