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Optimizing infrastructure

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Conventional physical infrastructure for urban low-income housing is extremely expensive in relation to income levels. Based on information contained in the 1989 World Development Report of the World Bank, $140 per year per household is a generous estimate of what the urban poor can afford to pay for both housing and services.

The tendency in many low income housing schemes, especially of the 'sites and services' type, has been to ignore the wide range of service options which are available and to use 'conventional' service levels in the region of $130 per household per year; to this must be added the actual housing cost of perhaps $100 per year. Subsidies are thus required from municipalities and other relevant agencies who can ill-afford to pay for operation and maintenance in the long term.

It is a gross over-simplification to regard infrastructure cost merely as a function of 'service length' in relation to site layout; the wide range of options within each sector have significantly different capital and maintenance costs in their own right. Infrastructure requires land reservation and there is therefore an associated land cost. When the land cost is high, overall costs may be minimised by selecting a technology which has a high construction cost but which requires the minimum land-take. There are also significant technical interactions between different technologies which have operational and financial implications.

RESEARCH PROJECT

To investigate these issues the authors have recently completed a research project which had as its aims:

1. To determine the range of technical options available within each infrastructure sector.

2. To explore means and appropriate sequences by which infrastructure can be upgraded over a period of time.

3. To explore the interactions between available technical options and their implications on the strategic planning of low income housing schemes.

4. To investigate the effect of upgrading infrastructure on the life-cycle costs through the development of 'sector cost models' using standard spread sheet programs on PC microcomputer.

The research methodology has been to assemble a range of servicing options based on different technologies available within each infrastructure sector and then to calculate the capital, operation and maintenance costs of each servicing option using baseline costs from the Far East (Philippines), Africa (Lesotho) and India.

Total Annual Cost per Household' or TACH is used as a cost indicator. The TACH is obtained by amortizing the present value life cycle cost over twenty years using a discount rate of 5%. The low discount rate is used to prevent replacement costs and future maintenance costs being rendered unimportant by the mechanics of the discounting procedure. TACH can easily be related to household income and therefore provides a relatively simple means of investigating the affordability of the different servicing options.

A vast number of permutations of different servicing options can be assembled from the technologies identified; a total of 31 different options were studied. In addition, each of these options was tested against the variables:

- -plot size (30 to 500 square metres in six steps)
- -plot shape (frontage-to-depth ratio between 1:1 and 1:4)
- -site layout (rectilinear cluster or linear layout)
- -land cost (US $0.5-$10 per square metre)

In order to assist in the data processing, a microcomputer model using the spreadsheet LOTUS 123 was developed. The model incorporates facilities both for design and upgrading of services with lifecycle costs and TACH calculated for a specified servicing option using predetermined dimensions and unit costs. The model comprises six independent modules:

- -site layout
- -roads and access
- -sanitation
- -water supply
- -storm and sullage drainage
- -power supply

The site layout module is used first to determine the land required for access for a wide range of access types; the roads and access module calculates the TACH having made decisions about the replacement values which depend upon the upgrading sequence specified by the user; the drainage module uses the 'rational method' of storm drainage design to calculate runoff, and the Manning equation to size the drains, relevant catchment data must be input by the user; the water supply module matches the demand requirements to the sanitation system which is specified, appropriate pipe diameters are calculated; the sanitation module calculates the required sewer size (if required) for that option; the power supply module calculates system costs including ancillary equipment such as transformers for both overhead line and underground cable systems.

PROJECT RESULTS

The choice of technology affects and is affected by many factors, including plot size and housing density, site layout and access requirements. Many of the technical options available for infrastructure have minimum access requirements for both construction and maintenance of the services provided. If the site infrastructure is to be upgraded over a period of time, it is vital that the access provided does not in any way restrict the future development of the site. For example, land reservation for an eventual power supply must be included in the initial site planning even if the supply is not to be provided in the first instance.

There are many interactions relating to technological compatibility. The choice of a particular technology in one sector may place restrictions on what is appropriate within another sector. For example, if on-plot latrines are chosen for sanitation, careful consideration must be given to sullage disposal. In turn, sullage disposal technology interacts with plot size; if large plots (>100 m^2) are in use, on-plot soak pits can be used, otherwise other disposal means must be used.

Interactions have an important effect on the cost of infrastructure. For example, if sewerage is used as a means of sanitation, a high level of water supply service involving individual house connections is also required which further increases the cost.

The cost of various servicing options for rectilinear cluster and linear layouts was investigated. The cost is a function of the physical size of the site and we have therefore restricted the analysis to a group of 40 plots in an idealised cluster.

The analysis is based on the actual values of TACH; the problems of 'who pays' and ease of cost recovery are outside the scope of this paper.

Four typical servicing options were investigated; option 1 represents a typical 'conventional' high level of service. Figure 1 shows the variation in TACH with plot size for different service options using the Far East case study data. Savings of between 40%-60% can be achieved by using more appropriate lower service levels such as options 2 & 4; Figures 2 & 3 show the results for the Africa and India case study data. The data shown is for low land cost; whilst increasing the land cost causes the TACH to increase, the principles of the interpretation which follows remain unaffected.

Such major potential cost reductions are of great significance and it is important to attempt to separate out the effects of the various infrastructure components to see which are the most significant. The bar charts shown in Figure 4 summarise the potential cost reduction which can be achieved through the selection of appropriate technology in each infrastructure sector over the full range of plot size, layout, plot ratio and land cost.

The choice of sanitation technology has the greatest potential to reduce costs; savings in the range 30% to 50% of the total servicing cost are possible through the choice of on-plot pit latrines as opposed to sewerage. The sewered option includes a cost for appropriate sewage treatment using waste stabilization ponds. In addition, household connections for water supply are necessary in order that the sewerage system functions adequately and this adds significantly to the TACH.

Significant but lesser savings have been identified through:

- Limiting the access width within the cluster or street from 5 metres down to 2.5 metres; note that for 500 m^2 plots, only 5 metres access was considered and therefore the percentage cost reductions shown refer to the 250 m^2 plot size rather than 500 m^2; this is more important at higher land cost and large plot size.

- Using the 'road as drain' option which reduces both the service land required and the construction cost.

- Investigating cheaper road construction such as profiled earth or gravel or local paving stone; this will lead to concomitant reductions in drainage cost.

The alternatives for solid waste disposal and power supply seemed to have little effect.

The layout has an important effect on service cost; in general, the linear layout is between 17%-26% cheaper than the rectilinear cluster over the full range of servicing options, plot size and land cost.

The plot ratio can also significantly affect servicing cost; the cost difference ranged from 5%-33% with square plots being more costly to service than plots having a short frontage compared with their depth. In addition:

-low cost servicing options are less sensitive to plot ratio;

-cluster servicing costs are less sensitive than linear layouts to plot ratio;

-servicing costs for small plots are less sensitive to plot ratio than are large plots;

-high land cost results in a greater sensitivity to plot ratio.

For minimum sized plots using the cheapest servicing option, the effect of plot ratio on servicing cost is not significant, giving only about 5% difference. This is a useful finding in relation to upgrading schemes on a small, irregular shaped sites where plot shapes and layout may have to be irregular.

The authors believe the research findings to be unique in respect of the range of variables investigated and in the quantitative substantiation of many issues which have in the past only been referred to in a qualitative way. The potential impact of the findings upon infrastructure costs for urban low income housing is enormous.

CONCLUSION - priority tasks for follow-up

The personal computer based spreadsheet models prepared for use in the research are an efficient method of analysing all the variables associated with services. Because they can be readily programmed to accept specific data relevant to any particular location they could be used in engineers and planners offices in many countries to optimise services provision.

The most significant factor in infrastructure provision distinguished by the lifecycle cost model is sanitation.With the large savings to be made from using on-plot technologies as opposed to sewerage there is an urgent need to investigate more fully the potential for using improved latrines on small plots. The technology of on-plot sanitation is well understood and accepted in rural areas and for large plots(400 m^2 to 500 m^2) in urban areas. However, this research has proved that there are significant savings to be made by using on-plot sanitation on plot sizes as small as 30 m^2 to 50 m^2 (as has already been demonstrated in India).

Areas to investigate include the environmental pollution risks of a high density of on-plot latrines, For an improved ventilated latrine there is a need to investigate vent pipe heights in built up urban areas, which can result in wind shadowing and failure of the odour and fly control mechanism.

The second priority for savings is related to drainage. One of the methods identified to improve drainage at reduced cost is the construction of a 'road-as-drain'. Examples have been noted, primarily in India, but no research has yet been carried out to prove the concept to a point where it can be promoted with confidence in other parts of the world.

With regard to the management of services provision on low income housing sites it has become apparent that the conventional municipal council approach often cannot satisfy the demand for regular repair and maintenance.

Whereas previously the boundary between 'private' and 'public' goods has been the house plot boundary, our research suggests that this could be moved out to a 'local area' boundary with the municipality responsible only for bulk transmission and bulk disposal. Further research is required to investigate the legislative framework, the municipal regulations and the bylaws necessary to support this approach.

Acknowledgement

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Servicing options

	Option 1	Option 2	Option 3	Option 4
Access width	5m	2.5m	255m	2.5m
Storm drains	Lined	Road-as-drain	Road-as-drain	Road-as-drain
Sanitation	Sewerage	Pit latrine	Sewerage	Pit latrine
Water supply	House connections	Public standpost	House connections	Public standpost
Sullage disposal	Sewerage	Lined sullage drain	Sewerage	Lined sullage drain to rear
Roads	Sealed surface Paved to rear	Paved	Paved	Sealed surface Paved to rear
Power	Overhead lines	Overhead lines	Overhead lines	Overhead lines

(* except for plot sizes > 100m^2 where soakpits were used)

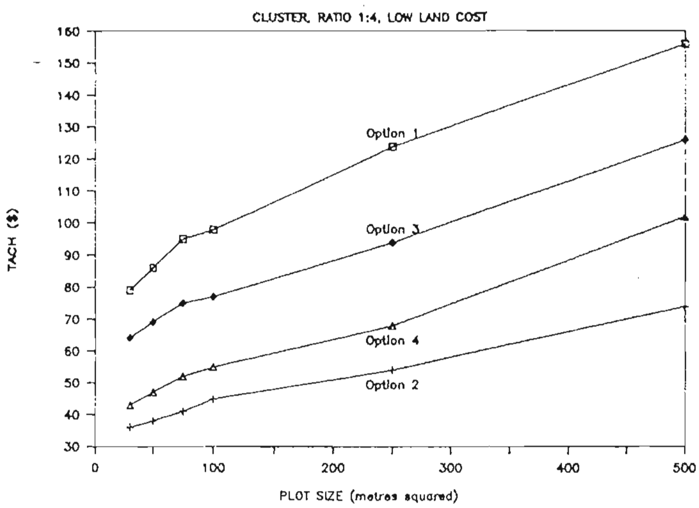

Figure 1. Service Option Cost, Far East

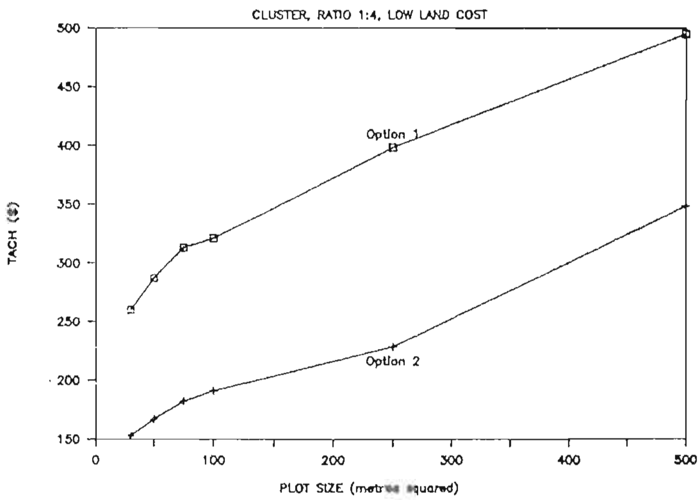

Figure 2. Service Option Cost, Africa

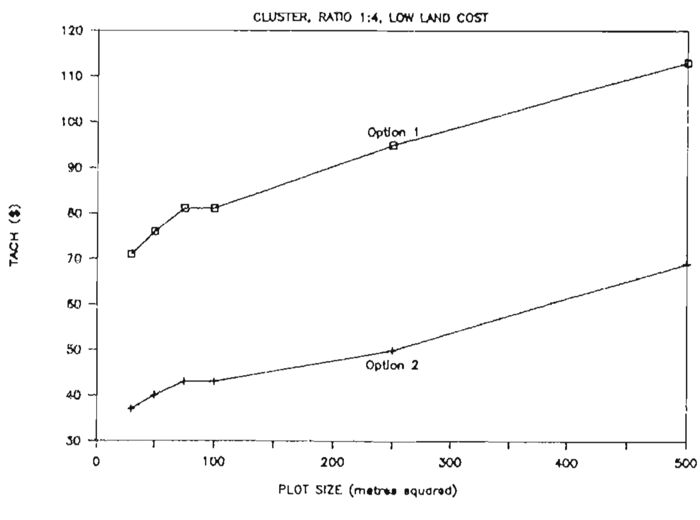

Figure 3. Service Option Costs, India