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Science for Development: A Housing Case Study

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Abstract

The current international focus on and investment in Science and Technology (S&T) research is aimed at maximising economic, social and environmental benefits to the community it serves (DFID 2005; Fan 2004).

Accordingly the CSIR was approached by the Department of Science and Technology (DST) to make recommendations with regard to alternative technologies that would contribute to achieving sustainable development imperatives in a subsidised housing project in Kleinmond, Western Cape.

In responding to DST's request, the CSIR determined an S&T contextual approach and applied a Packaged Development Project Approach (PDPA) that could serve as a model for further S&T interventions in the future roll-out of subsidised housing. This approach maximizes the various scales at which projects of this kind operate by providing rigorous proof of concept for integrated, community-based, innovative technology interventions to meet the community goals of a developmental state such as South Africa.

A workshop was held to identify the innovative technologies that could be applied attended by senior researchers and representatives of the Regional Government of the Western Cape, the Overstrand Municipality, and the municipality's professional consultants. The opportunities for technological interventions were identified, as well as the innovative

technologies suitable for each of the identified opportunities. The opportunities included municipal services; township layout; and construction technology.

The identified technologies for municipal services include re-designing the roads; re-using local soils rather than importing soils for the road bases and sub-bases; rainwater harvesting; sustainable urban drainage systems; waste and soil water treatment; and energy generation and saving.

No technologies were identified for the township layout although recommendations were made about orientation in certain cases.

The identified technologies for housing construction included a concrete framed structure rather than a masonry plinth; lightweight infill panels; and exploiting the repetitiveness of the units and the scale of the project to prefabricate as many of the construction components as possible, in line with the current concept of Modern Methods of Construction (MMC).

The paper concludes with a description of the anticipated way forward.

Introduction

This section briefly describes the background to the project, the need for S&T interventions, the purpose of the intervention, and the scope of the intervention.

History and background

A Social Housing Plan for 611 houses in Kleinmond was approved in 2006 as a Special Project of the Provincial Ministry of Housing in the Western Cape. The construction of these 40 square metre, one-bedroomed houses was scheduled for completion during 2007/08. The development, located on the last remaining vacant developable portion of land within the municipal boundary, is adjacent to the boundary of the Kogelberg Biosphere Reserve in Kleinmond, a reserve declared and registered with UNESCO in 1998 due to its diverse and rare plant habitat. The site slopes steeply, varying from 1: 12 to 1:6.

Kleinmond is located on the east coast of the Western Cape, between Gordon's Bay and Hermanus. Essentially a sea-side vacation village, it nonetheless manifests all the challenges facing South Africa. The population in the late 1980s was about 1800 whites (who lived in the main village) and 2500 Coloureds (who lived in a segregated area known as Proteadorp). With the removal of influx control – the Western Cape was previously reserved for Whites and Coloureds only – a number of Black families migrated into the area in search of work. As land was not set aside for Black South Africans, these families established an informal settlement – known as Overhills – in an area located next to the refuse dump site and in the reserve set aside for high-voltage overhead electric cables.

With only 24 per cent of the adults living in the informal settlement employed, social problems are rife (including high rates of TB and HIV/AIDS). There are no skills training facilities in Kleinmond, and the nearest facilities are between 30 and 45 kilometres away. No public transport, apart from privately owned taxis, exists between the towns.

Need

The development of this housing project raises two major needs. First, the planning of Kleinmond was made on the assumption of a lower total population: thus the existing municipal infrastructure is currently operating at close to full capacity. Second, unemployed persons are neither able to pay for local municipal services nor expand the basic housing unit. The steep slope of the site further hinders expansion as a substantial amount of money is needed to create a level platform. The need therefore is to reduce the

burden of the additional load of the 611 housing units on the existing municipal infrastructure, reduce the dependence of the house owners on municipal services, and facilitate an easier expansion of the basic dwelling unit.

In addition, the delivery of infrastructure, including housing units, consumes significant amounts of raw materials. Edwards (2002:10) submits that construction consumes:

- 50 per cent of all resources globally
- 45 per cent of energy generated to heat, ventilate and light buildings, with an additional 5 per cent for the construction process
- 40 per cent of water used globally for sanitation and other uses
- 60 per cent of prime agricultural land lost to farming for development purposes
- 70 per cent of global timber products

The estimated housing backlog in South Africa is 2.4 million units, requiring 300 000 units to be built per annum if the backlog is to be cleared by 2014 (Kotzé 2007:12). Utilising conventional technologies and construction practices to meet these demands will seriously undermine the natural resource base of South Africa: little wonder then that the delivery and maintenance of construction works (buildings and civil infrastructure) absorbs capital in a manner that is not sustainable (Edwards 2002:10), that is not acceptable (Woudhuysen and Abley 2004:1), and that tarnishes the image of the construction industry (ILO 2001:1).

In recognition of this need the Overstrand Municipality formally applied to the DST for grant funding to identify and implement innovative “technologies aimed at improving the sustainability of the project while reducing capital and operating costs” (Overstrand: April 24, 2007). On the basis of this request, DST invited CSIR to assist in the identification, development, implementation and monitoring and evaluation of the innovative technologies having regard for the development of a S&T Model that could be applied to similar applications.

Purpose statement

The purpose statement for the project is best described in the following thesis and hypothesis.

Thesis – the unit density of an existing municipal area can be increased without requiring substantial additional municipal infrastructure expansion.

Hypothesis – targeted technological interventions can raise the independence of new development projects from municipal services.

Scope

The scope of this paper is limited to illustrating the exploration of the range of technological interventions available having regard for the specificity of the location and the nature of the project. As directed research had not yet commenced at the time of preparing this paper, the author is unable to confirm the final nature of the technology interventions agreed to, nor to provide any results indicating the success or otherwise of the targeted technological interventions.

With regard to the application of innovative technologies, and given the late engagement of the CSIR in the project, the technology approach adopted by the CSIR was to only use those technologies that satisfy the requirements of the National Building Standards and Building Regulations Act (Act 103 of 1977). This was done to safeguard the interests of the beneficiaries as well as the Overstrand Municipality, DST and CSIR.

Research methodology

In undertaking the preliminary investigation of the technological interventions available to this project, the following research methodology was adopted.

Data gathering

The data used was gathered from information held by the local authority, Overstrand Municipality, and the Project Managers appointed by the municipality, Arcus Gibbs Engineers. The data consisted of a Geotechnical Report; the proposed township layout; prototypical housing unit plans, sections and elevations; and costing estimates.

Data interpretation

The data provided was interrogated to establish the following:

- Soil type and depth
- Site slope
- Site orientation
- Location of site relative to adjacent environments, both natural and built
- Climatic conditions (solar radiation, wind, rain)
- Capacity and location of existing municipal infrastructure

Subsequent to this, a workshop was held where senior researchers from the Architectural Sciences, Construction, and Integrated Planning Competence Areas of the CSIR Built Environment Unit met with representatives of the Regional Department of Housing in the Western Cape, Overstrand Municipality and the professional consultants, to analyse the data and identify opportunities for intervention and responsive innovative technologies that could maximise those opportunities.

S&T contextual approach

As stated in the beginning, the focus on and investment in science for development is meant to demonstrate real improvement in the quality of life of the recipients. The S&T approach should however, and does, offer more than this. It may well be that a development can achieve self-sufficiency from a services point of view: however, self-sufficiency must aim to include economic, social, environmental, technological and ecological issues. To achieve this, certain basic research questions need to be answered, such as:

- What are the thresholds/tipping points of the approach (income, number of units, number of inhabitants, size of land portion, access to jobs, rainfall patterns, wind speeds, number of solar hours, etc.)?
- What S&T is available that will extend and maximize the thresholds/tipping points?

Arising out of the research methodology applied to this project (as captured in the sections above), the following S&T context for determining which technology options should be recommended was developed.

Treat development holistically

This paper suggests that any technology proposals be treated holistically, that is to say, that all proposals support a broad-based and common set of goals and objectives. In this regard, consideration must be given to addressing those economic, environmental, social, technological and ecological challenges facing a developmental state such as South Africa. In particular, the recommended technologies must address anticipated energy and water shortages facing the country.

Thus certain technologies that are known to offer other benefits, such as job creation and entrepreneurship, should be favoured over those that do not. Similarly, potentials to be found in specific geographic conditions of the site and its surrounding areas, for example, local soils, may well add value to the development if properly exploited.

Local authorities are increasingly unable to sustain the expansion of urban areas within their jurisdiction: thus, if any development proposal is to serve as a model development, it must demonstrate an ability to operate in a manner that will not further undermine the financial sustainability of local authorities. One of the ways it can do this is to reduce the dependence of the development on municipal services. This approach should be explored at the level of the entire community, and not just at the level of the housing units.

Scaled-up technology

Different technologies operate optimally at different scales. It may well be that a range of scales of technologies are employed, for example, wind generators in conjunction with solar collectors. The introduction and implementation of sustainable urban drainage systems (SUDS) must be considered together with a range of other grey, yellow and black water treatment technologies. Furthermore, attention must be given to the efficiency of the basic housing unit to ensure that the unit is operating optimally.

Assess the impacts

To accurately assess the impacts of the proposed technologies requires that a base technology performance level be determined in conjunction with the alternative technologies proposed, and that the technology be applied under similar conditions. As already stated, certain technologies are more effective at certain scales than others: thus, the overall development must also be assessed for scale opportunities and all technologies assessed against the range of scales offered within the development.

Reduce extreme poverty

Virtually all developing countries face critical decisions about the best strategies for managing the massive transition of rural populations out of agriculture anticipated in the coming decades. Challenges that this presents are related to determining how urban growth can be made more effective for poverty reduction and how new forms of urban growth can be captured cost effectively.

Development technologies that support short-and long-term job creation, are labour intensive, and create opportunities for skills development and training are among the strategies that can support sustainable economic growth within urban communities.

A Packaged Development Project Approach

In support of the above, development proposals could be 'packaged' across a range of innovative technology interventions aimed at supporting the overall goals and objectives of a developmental state. A Packaged Development Projects Approach (PDPA) embraces the vision of the Millennium Declaration, which is based on the overall paradigm of good governance and developmental policies based on science and the scaling-up of best practices.

Aim

The aim of PDPA is to:

- Provide rigorous proof of concept for integrated, community-based, innovative technology interventions to meet sustainable community goals in South Africa
- Identify mechanisms for national-level scaling-up of science-based interventions to support the design of sustainable development strategies

Underlying principles

The underlying principles of the PDPA include:

- Interventions based on proven, science-based research (scientific, technological, biophysical and socio-economic) combined with the best local knowledge
- Identifying appropriate technologies within the budgetary constraints
- Building on existing community, government and non-governmental programmes in the area
- Community empowerment through participation and leadership in design, implementation, monitoring and evaluation
- Building capacity and empowerment at the local level
- Strengthening local institutions
- Linking with and obtaining support from local, provincial and national government
- Consistency with national plans for interventions
- Scaling-up by increasing the technologies quantitatively and qualitatively
- Providing effective synergies between 'bottom-up' approaches and 'top-down' approaches by linkages through enabling policies

Scaling up approaches

A preferred means of scaling-up is through local, provincial and national level involvement – using the PDPA as pilots for demonstrating the concept and developing instruments and demonstrators that can then be managed and expanded by governments.

Three types of packages enable the scaling-up of interventions:

Type 1 – this represents the core approach, where interventions are rigorously monitored, their outcomes quantified, and proof-of-concept established at project level.

Type 2 – will use a cluster approach where the focus is placed on scaling-up the integrated, community-based strategies for achieving sustainable communities around a number of Type 1 projects.

Type 3 – will replicate and scale-up successful integrated, community-level interventions to achieve sustainable communities beyond the immediate vicinity of Type 1 and Type 2 approaches.

Identification of opportunities for technology interventions

In order to identify appropriate innovative technologies opportunities for intervention had to be identified. Essentially three categories of opportunity were identified: first, municipal services; second, township layout; and third, the construction technology applied for the individual units.

Municipal services

Municipal services to be supplied to the site include roads, water reticulation, storm water reticulation, waste and soil water reticulation, refuse removal and electrical reticulation.

Roads

The construction of the internal roads serving the project is particularly costly due to the specific nature of the site, i.e., the steep slopes. Apart from the challenges of laying conventional bitumen pavement on steep slopes, namely, surface creep, a cut-and-fill approach has to be used to create the road reserve, requiring bank stabilization on the upper and lower edges.

Opportunities for intervention that were identified included alternative and more stable pavement finishes, reducing pavement width, and reducing the extent of cut-and-fill.

Water reticulation

Given the water scarcity currently facing the Western Cape, and the expected increase in drought incidents as a consequence of climate change, the secure provision of water assumes a critical importance in the region. Opportunities identified for intervention included rain water tanks, collecting surface water, and low-flow water fittings.

Storm water reticulation

An opportunity immediately identified due to the slope of the site was the collection of surface water into one or more collection tanks. Dependent upon the location of these collection tanks, they could provide a horticultural opportunity to support the declared biosphere, and provide sprinkling for the sports field of the adjacent school. In addition, the steep slopes above the site result in discharge of considerable surface water across the site: collecting and diverting this water away from the site would lower the engineering impact on the site.

Waste and soil water reticulation

The additional waste and soil water load resulting from the additional 611 houses will impact significantly on the existing sewerage treatment plant of the municipality, especially during the summer months when the capacity of the existing facility is severely stretched as a result of the summer visitors. Opportunities identified included the separation of waste water from soil water, and the treatment and re-use of the waste water on site, and the retention and/or treatment (partial or in-full) and re-use of soil water on site and the discharge of solids into the municipal system.

Refuse removal

The collection of internal refuse and the sorting thereof for recycling purposes is one of the identified opportunities from a job-creation perspective, but does not constitute a technology intervention. However, a predominance of certain materials, such as glass and paper, might lend themselves to the production of certain products, or income from recycling companies.

Electrical reticulation

The current short supply of electricity in South Africa generally is a clear opportunity for some technological intervention. An off-line capability will also benefit those who cannot afford to pay for electricity and therefore have to resort to cooking on open fires.

Township layout

Inadequate or inappropriate town planning often bedevils the opportunity to implement known sustainable development strategies such as north orientation: in the case of Kleinmond, the layout was dictated by two powerful existing factors, namely the steep southerly slope, and the southerly orientation of the sea-view. In most instances following the contours of the ground is the only option to reduce the extent of cut-and-fill, and this was done in the Kleinmond project. In addition, to overcome the unfavourable orientation, the bedroom was orientated north with the living room orientated south to maximize the extraordinary view. In some limited instances units are oriented west-east, partially in response to a particularly steep slope and partially in response to creating a significant urban streetscape. However, these units will definitely face an over-heating problem in the late afternoon, albeit in summer only.

Steep slopes are known to create associated problems, one of the more crucial being the discharge of services from the unit above across the land of the unit below. The maintenance of these flows is crucial for the efficient operation of the development as a whole.

Construction technology

The construction technology employed in the design of the units was identified as an intervention opportunity for a number of reasons. The design of the units follows that typically used in low-cost housing, i.e., single skin concrete block walling on concrete footings, steel window frames, timber roof joists and corrugated roof sheets. The consequence of this technology is the following:

- Due to the slope, a significant amount of cut-and-fill is required
- A significant amount of foundation walling is required to create a level platform on which to erect the unit
- A significant amount of stepped foundations is required
- A significant amount of foundation excavations is required
- A significant amount of stabilisation of the cut-face is required
- The later enlargement of the unit is expensive as the above consequences apply once again

Significant gains could therefore be made if an alternative technology that circumvented these consequences could be developed.

Identification of innovative technologies

Given the above list of possible intervention opportunities, the range of innovative technologies that could be applied in each case was considered.

Municipal services

With regard to the provision of municipal services, the following innovative technologies were identified.

Road widths and surfaces

Subject to the determination of traffic volumes within the project, it is likely that the trafficable road width be reduced to 3.5m for internal roads and 5.5m for collector roads. This change will reduce the amount of road works required, and the amount of materials to be used. The difference in the road reserve and the road width will be taken up with hardened surfaces also constructed from local materials.

With regard to the pavement surface, it is proposed that the bitumen surfaces be replaced with a 50mm thick reinforced concrete road. This technology has been successfully tested elsewhere by the CSIR and has the added benefit of being labour-intensive, thereby offering employment opportunities for the beneficiaries.

Use of local materials

A preliminary investigation of the Geotechnical Report indicated that the nature of the local soils might well be suitable for use in the construction of the roads within the housing project. The local soils might be used as a sub-base and a base for the roads, subject to further investigation and confirmation. Should this be viable, using local materials will save the costs of exporting the excavated material off the site and its dumping in some determined area, and the importing of other materials from a borrow-pit from other location.

Water reticulation

Pending the investigation of rainfall patterns in the area, it is proposed that roof water be collected and discharged into an individual water tank for each unit. This water could be used for domestic gardening purposes.

Sustainable Urban Drainage (SUD)

Subject to the determination of storm water catchment requirements and further examination of the soil types and slopes, it is suggested that storm water be collected and made available in two locations, i.e., within the Eskom overhead power line reserve and the school sports field. This may require some changes to the drainage layout, and the construction of 2 storage ponds/tanks the exact size of which will have to be established.

Should the above proposal prove to be risky (the management of the water quality is critical if health risks are to be avoided), then the storm water generated above the site should be arrested and diverted away from the site thereby minimizing the risks of flooding and reducing the total amount of storm water requiring collection and discharge into the municipal system.

Waste and soil water reticulation

Due to the location of the development site within the confines of an adjacent residential area, and given the nature of the slope and the type of soil predominant to the area, it is proposed that the risks associated with on-site waste and soil water treatment on steep, sandy slopes are too high. A suitable technological solution to minimize these risks will require a substantial intervention which ultimately undermines the sustainable development objective.

Refuse collection

As this opportunity has more to do with management than technology, no intervention is proposed at this time.

Electrical reticulation

Subject to a more thorough investigation with regard to total available solar hours on the site, solar radiation levels, wind speeds throughout the year, etc., it is proposed that a combination of neighbourhood-scale wind generators, solar water heaters, low-energy fittings, solar-powered street lighting, gas cooking units and thermal insulation be included in the development. The combination of reduced energy-demand due to improved thermal insulation, and the independent energy generating capacity of the above technologies may result in the project being energy-independent. This will clearly have significant benefits to the residents and to the local community who already face electricity outages due to a demand/supply imbalance. In addition, the achievement of electricity independence holds significant promise for the country as a whole.

Township layout

Due to the limited opportunities arising from the nature of the site, no suitable alternative technology interventions were identified. It was strongly recommended that efforts be made to minimize the westerly exposure of certain units, such as re-orientating the windows where possible and creating sun-screening devices.

Housing construction technology

Subject to further investigation, it is proposed that the masonry plinths of the housing units be replaced with a concrete frame structure, i.e., reinforced concrete slabs supported on 4 concrete columns. The advantage of this technology is that it requires minimum on-site excavation, less concrete foundations, and increases flexibility for later expansion.

It is further proposed that alternative infill panels be examined that offer higher insulation values and better moisture exclusion than the 140mm concrete blocks proposed.

While it may be that this technology may have higher initial capital costs, the technology offers the beneficiaries a solution that will facilitate later changes to occur in a safer and more cost effective manner.

In addition, and perhaps most crucially of all, maximum benefits must be derived from the scale of the development. Since the units are mostly all 40 square metres and of a uniform layout, the potential exists for prefabricating many of the components required off-site and assembling the partially or fully completed units on-site. Components such as complete roofs; pre-wired electrical looms; pre-plumbed water and drainage pipes; complete kitchens and bathrooms can be pre-manufactured and assembled, and fixed into position on site. This type of construction, known as Modern Methods of Construction, offers significant benefits such as:

- Quality can be better controlled
- Components can be tested for compliance before erection
- Time can be better utilized
- Less damage occurs to components
- Less waste is generated
- Delays due to inclement weather can be excluded
- Women can be more easily employed
- Working conditions are improved
- New skills are learnt
- New business opportunities are created beyond the scope of the particular project

Conclusion

This paper argues that in a developmental state such as South Africa, S&T is a powerful tool for supplementing other government initiatives around a basket of socio-economic benefits. The CSIR has applied a Packaged Development Projects Approach in this case study utilizing the Type 1 approach. It is still too early to evaluate its success or otherwise as the directed research has not yet commenced. However, future S&T research will develop the identified innovative technologies further, monitor its implementation, develop measuring instruments, and evaluate the interventions over a period of time. Pending the outcomes of the research, adjustments will be made so that an evidence-based S&T approach is used and continuously improved.

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