Ultimately the route to understanding how improvement in the sustainability performance of Hong Kong's buildings can be achieved is through the identification of the economic and environmental profiles of the buildings designs. It is at this stage where the commitment is made to use certain materials, construction elements and components, to the method of construction and the operational systems, and the lifespan of the buildings (Hong Kong Housing Authority, 2002). It is therefore at this point that suitable economic and environmental information must be delivered to the client and design team.

The best method of establishing such information is through the comprehensive life-cycle mapping of construction materials in terms of cost and environmental burdens of the existing building designs. This is not as difficult as at first it might appear. Hong Kong, unlike most other country's construction sectors, is dominated by a relatively standard design approach, called the use of reinforced concrete (Burnett, 1998). Equally Hong Kong has a substantial number of high-rise residential towers, of which the housing authority accounts for 48% of the total market supply (Census and Statistics Department, 2001). Therefore, studying this particular housing solution, that is one of just a few housing block archetypes, will be representative of Hong Kong's residential construction sector which in turn is a considerable proportion of the industry's total output.

Thus any move towards a more sustainable construction industry in the region needs to be sufficiently sophisticated enough to reconcile both economic and environmental impacts (Xu, 2000). It is for this reason that a unified methodology that includes both LCC and LCA is essential to discern 'real' and acceptable improvement strategies. The next section outlines the four stages of the methodology, which include: data collection, the creation of life-cycle models, comparative analysis and the development of improvement strategies.

Methodology

Regional data and selection of performance indicators

Carrying out a comparative LCA/LCC assessment throughout the full life cycle of each building type requires a comprehensive database of the costs and environmental impacts. These impacts result from the manufacture and delivery of all the

major construction materials, elements and components. Initial investigation showed that much published environmental material data had been generated in Europe or Australia. However, validated regional data was considered important, so it was decided to restrict the European data on embodied energy of construction materials data to a range of key construction materials considered to be applicable for use in Hong Kong (Chen *et al.*, 2000).

However, good local data on the operational energy consumption per building (the energy consumed during the operational life of the building: e.g. cooling, ventilation and lifts) were available, as were reasonable local data on the material consumed in the repair and maintenance regimes. Good local data were also available for waste and together with the above data, it was then possible to create a reasonably good life-cycle model.

Finally, very good local cost data were available throughout the building life cycle and thus the study was able to create building life-cycle models for each building type. Thus the assessment took into account the full life cycle of all the buildings, from the manufacture of the building components and elements from raw materials, through the construction and operational life of the buildings and finally to the end of the buildings lives. Assumptions had to be made of course about the maintenance regime of the Integer Tower. The performance of each building type was then compared in terms of the following indicators:

- ***Energy both embodied and operational*: because energy is a robust indicator of environmental impact, and crudely assesses impacts to the biosphere. It measures global impacts in the sense that it is a resource that is being depleted. Moreover, data are available**
- ***CO_2 both embodied and operational*: because it is an indicator of greenhouse gas emissions and data are available**
- ***Waste*: differentiating between that going to landfill and that recycled or reused. This is a local issue, which means the consumption of very scarce land. Nevertheless, it is considered important as estimations indicate that the quantity of waste annually produced in Hong Kong is predicted to rise rapidly. Very accurate data has emerged from the inventory analysis proposed (Koenig *et al.*, 2001)**
- ***Cost*: because not only it is the basis of many, if not most, construction decisions in Hong Kong, but also is a key economic indicator, and goes much of the way to satisfying the assessment of economic sustainability**