506: The Integrated Resource Management (IRM) model – a guidance tool for sustainable urban design

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Abstract
Traditionally the master-plan of an urban design development is centred around the land use schedule proposed by an urban design team. Technical teams (for transport, energy, waste, water, etc.) then each propose their individual strategy to maximise the sustainability of the site within their field of expertise. The methodology we present challenges this fragmented approach to sustainable design by assessing the sustainability of the whole design set, i.e. land use schedule and various strategies proposed, all at once. The IRM model processes inputs provided by each technical team, its calculations reflecting their respective strategies. It then outputs *quantitative* values to a comprehensive list of key performance indicators (e.g. energy consumption or total greenhouse gas emissions) defined within a framework set to appraise the sustainability of the whole design.
Applied to a new development master-plan it has proven itself useful in either warning technical teams against inconsistencies between their individual strategies or in informing them on possibilities of improvement of the project's sustainability performance through a better integration of their strategies. Most importantly it has brought urban designers and technical teams to realise the interdependencies between strategies and the necessity to foresee these early enough within the design process.

Keywords: sustainability appraisal, integrated resource modelling, urban master-planning, integrated urbanism

1. Introduction

1.1 Motivation
As more and more of the world's population enjoys a better standard of living, assuring that as many people as possible enjoy a socially balanced, economically prosperous life without impacting negatively on the environment and resources that ensure our wellbeing is the challenging task embodied by sustainable development. With already half of the world's population living in cities, designing cities sustainably seems to be a target of choice [1].

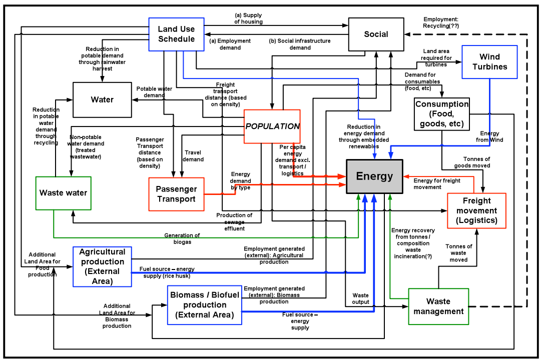


Fig 1. Interdependency of the different work streams involved in the master-planning of a urban design project.

This in general involves the collaboration of different technical and designer teams.[1] Until recently designing a sustainable city usually implied that each team would propose their most sustainable strategy independently of the other teams. This approach is limited because it neglects the fact that each technical work stream influences all the others (see figure 1). The strategy chosen by each team will have an impact on that of all other teams, e.g. the optimal land use schedule from the urban design team might make the energy team's strategy impossible to implement. We advocate using a holistic approach to sustainable urban design, i.e. an approach where all technical teams interact with each other to develop a strategy whose overall outcome is more sustainable than the sum of optimal individual solutions. This approach requires a methodology that will favour an interaction between teams as well as a tool that can assess the effectiveness of their collaborative strategy in terms of sustainability.

1.2 State of art
What we present in this article is not simply a calculation tool but rather guidance on how to conduct the sustainability appraisal of an integrated urban design within which the IRM model plays a central part. Other more sophisticated software tools are able to calculate aspects of the sustainability performance of an urban development. The Sustainable Urban Neighbourhood tool (SUNtool) for example calculates the flow of resources (waste, water, energy) within a neighbourhood of up to 1000 buildings for each hourly time step of a simulation

1 From this point on we will call these teams of experts "technical teams". For a complete list of these teams see chapter 2.2.

period up to one year [2].[2] Our approach does not have this level of complexity but, as this article will show, it is nevertheless better at adapting itself to the realities of an urban design project by offering itself as a platform for discussion and interaction between technical teams and foremost by adapting itself to the level of detail of each phase of the master-plan and the level of detail of the information that each team can provide at each of these phases.

1.3 Structure of article

Chapter 2 presents how the IRM model is used within the sustainable appraisal of a new development's master-plan; this includes defining a Sustainability Appraisal Framework (SAF), using the IRM model as a calculation tool and finally using the IRM model as a means of interaction with the technical teams involved in the master-planning process.
Chapter 3 then gives the example of an urban development to which this approach has been applied and discusses the feedback we have gathered from this experience.
Although the examples we present here are the master-plans of new urban developments the approach presented can be applied in the same way to urban regeneration projects as well as to the monitoring of existing sites in their operational phase.

2. Methodology

The approach we present here is designed to introduce, optimise and report on an integrated inclusion of sustainability into urban design.

2.1 Sustainability Appraisal Framework (SAF)

In order to do this we need a framework within which we can appraise the sustainability of each design option proposed by the group of technical teams. Some countries have already integrated the consideration of sustainability within their planning legislation; this is the case of the UK that has adopted the SA/SEA (Sustainability Appraisal / Strategic Environmental Assessment) for the sustainability appraisal of its Development Plan Documents. Countries for which this is not the case already have unofficial guidelines to sustainability expected to soon be adopted by their legislation. The SA/SEA defines a set of objectives to which regional and local planning documents have to comply.[3] We expand the set of objectives (defined by local, regional or national authorities and therefore proper to the location of our development) by defining a set of *quantifiable* key performance indicators (KPIs) that can be associated with each objective of the SA/SEA and give a complete appraisal of the objective in question. Each KPI is given a baseline target, a "project target" and a more ambitious "stretch target".

This forms the basis of of the Sustainability Appraisal Framework (SAF), determines its scope and its interpretation of the term "sustainability". As the owner of the masterplan and the assessment of its sustainability performance the client will participate in finalising the SAF and therefore determining which aspects of sustainability will be emphasized. Nevertheless the minimum set of sustainability objectives provided by the (local, regional and/or national) SA/SEA will always serve as a basis for the SAF as satisfying these objectives will be most relevant for obtaining planning permission. The client's aspiration to produce a "more sustainable" masterplan will translate into more ambitious "project" and "stretch" targets for chosen indicators and therefore for certain aspects of sustainability. However once the SAF has been finalised our reporting of the masterplan's performance is rigorous, i.e. targets are either met or not and a failure to meet a target is not compensated by the success of another.[4] We provide an interpretation for the result of each KPI but it is left to the client to make use of the overall results in a way that serves them best.
The value of the KPIs will be iteratively calculated with the IRM model during the master-planning process and compared to the targets in order to assess the present state of sustainability of the overall strategy. This will inform the technical teams on the success of their strategies and the possibilities of improvement. It can also be used to report to the client whether the strategies to which they have agreed to are able to meet the targets they have set themself.

2.2 The IRM – a calculation tool

The IRM model is used to produce a maximum of information about the combined strategies of the technical teams; from this it calculates numerical values for the indicators defined by the SAF. To produce these calculations the IRM receives inputs from the technical teams involved in the design project. A typical list of technical teams would include:

- urban design experts (urban planners, landscape designers, agricultural experts),
- socio-economic experts,
- transport planners,
- logistics experts,
- building design experts (architects, building services' engineers, building physicists),
- energy supply experts,
- water engineers,
- waste management engineers.

[2] For more information on SUNtool see also the "www.suntool.net" website.
[3] The Office of the Deputy Prime Minister offers guidance to this process in [3].

[4] This approach is in line with the "strong" sustainability model.

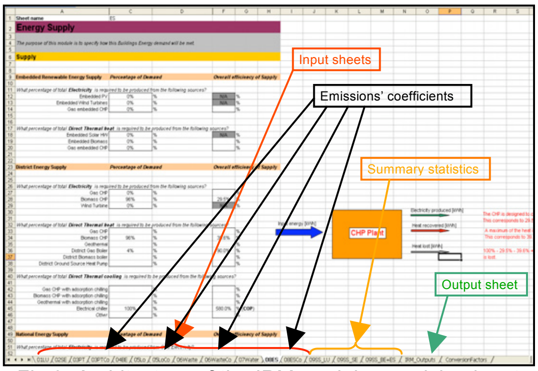


Fig 2. Architecture of the IRM model comprising input sheets filled in by technical teams, sheets for emissions' coefficients, summary statistics and the output sheet shown in figure 3.

The data provided by the technical teams is entered into input capture sheets (see figure 2) developed in collaboration with the technical teams and tailored to the needs of the IRM model and in alignment with the outputs of the technical teams' models. Life cycle assessment experts provide extra information on the greenhouse gas (GHG) and air pollutant emissions that can be associated with the production, transport and combustion of fuels consumed by the modelled development (an example of this is given in the next paragraph). The entered data is processed to produce an extensive list of so-called summary statistics (see figure 2). This information is then further processed to finally produce numerical values for the KPIs (see figure 3). Generic calculations and data sets at the core of the IRM are adapted to the location of the development and to the strategies proposed by the teams.

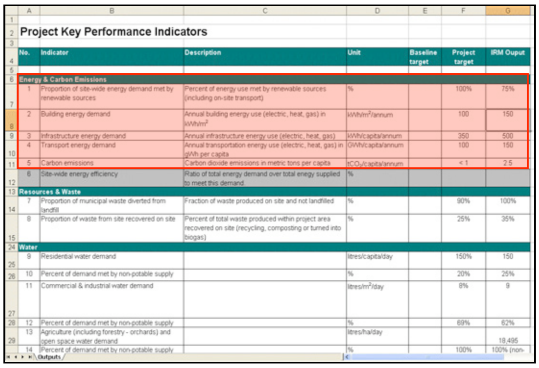
An example of a KPI whose value is calculated by the IRM model is the amount of GHGs emitted during the operational phase of a project. GHGs are emitted by:

- transport (logistics and passenger transport, on the site and to and from the site),
- the fuel consumption for the on site or off-site production (plus the "pre-combustion" GHGs emitted to process and transport the fuels), of energy (heat, cold, electricity, fuels) needed on the site and
- the management of waste (emissions due to incineration, anaerobic digestion, composting or land fill, or the off-setting of GHG emissions by reusing or recycling waste).

2.3 The IRM – a tool for interaction

Although the IRM model is a stand-alone software programme it is best used when it initiates a discussion between the technical teams and the "IRM team" (i.e. experts responsible for the IRM model), and amongst the technical teams themselves. In the first case it is essential that the members of the IRM team understand the strategy (technical details, assumptions made and quality of data) underlying the data provided by each technical team. As the IRM team obtains this knowledge from all technical teams it is well placed to make an overall assessment of:

- the inconsistencies between the technical teams strategies,
- the potential of better coordination or interaction between the individual strategies,
- the aspects of the project that have failed to be covered by the teams
- and above all of the overall sustainability of the project.



Project Key Performance Indicators

No.	Indicator	Description	Unit	Baseline target	Project target	IRM Ouput
Energy & Carbon Emissions						
1	Proportion of site-wide energy demand met by renewable sources	Percent of energy use met by renewable sources (including on-site transport)	%		100%	75%
2	Building energy demand	Annual building energy use (electric, heat, gas) in kWh/m²	kWh/m²/annum		100	150
3	Infrastructure energy demand	Annual infrastructure energy use (electric, heat, gas)	kWh/capita/annum		350	500
4	Transport energy demand	Annual transportation energy use (electric, heat, gas) in gWh per capita	GWh/capita/annum		100	150
5	Carbon emissions	Carbon dioxide emissions in metric tons per capita	tCO_2/capita/annum		< 1	2.5
6	Site-wide energy efficiency	Ratio of total energy demand over total enegy supplied to meet this demand	%			
Resources & Waste						
7	Proportion of municipal waste diverted from landfill	Fraction of waste produced on site and not landfilled	%		90%	100%
8	Proportion of waste from site recovered on site	Percent of total waste produced within project area recovered on site (recycling, composting or turned into biogas)	%		25%	35%
Water						
9	Residential water demand		litres/capita/day		150%	150
10	Percent of demand met by non-potable supply		%		20%	25%
11	Commercial & industrial water demand		litres/m²/day		8%	9
12	Percent of demand met by non-potable supply		%		69%	62%
13	Agriculture (including forestry - orchards) and open space water demand		litres/ha/day			18,495
14	Percent of demand met by non-potable supply		%		100%	100% (non-

Fig 3. The output of the IRM model – the numerical values of the key performance indicators.

Having this overarching view of the project with a focus on its sustainability the IRM team can then inform the team managing the project as well as the technical teams on its assessment and possibly advise them on how they can improve the overall performance of the project's sustainability.

The numerical results output by the IRM model can be used at various stages of the master-planning project. They can be used *internally*, providing the technical teams with a better understanding of where the project lies in terms of sustainability, how their strategy contributes to this performance and how they can improve this. The results can also be used for *external reporting* first of all to the client and later on to authorities responsible for providing the client with planning permission.

By discussing individually with each technical team, by being aware of their individual strategies and by being able to assess the sustainability performance of the overall strategy as well as its sub-strategies, the IRM team can function as both a central component of the project's team force assisting and informing technical teams, as well as a reporting body informing the project management and the client on the consequences of their choices. This added value to the project has already been observed in the couple of case studies the IRM model has been applied to.

3. Results

3.1 Case study

We will mention here the experience gained during the master-planning process of an average sized (approximately 3500 dwellings), mixed use UK new development to be built within the next 15 years. This project included 11 technical teams from 6 different companies, covering the list of disciplines mentioned in chapter 2.2. The IRM team came midway into the project, worked on it for 4 months and was able to produce 2 series of IRM calculations.

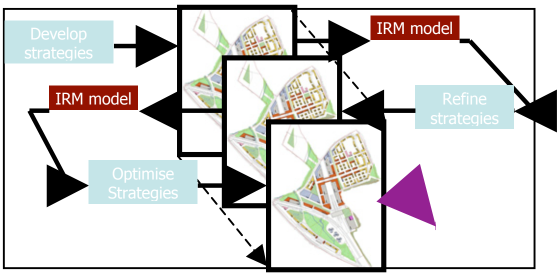


Fig 4. The iterative use of the IRM model contributes to the improvement of technical teams' strategies.

3.2 The IRM model – part of the master-planning process

By discussing with the technical teams and gathering the necessary input data for the IRM model the IRM team was able to assist the technical teams by:

- recognising and highlighting inconsistencies between their own strategies,
- informing on important aspects of the project that had not been covered by any of the teams,
- informing the teams on the opportunities of better integration
- and ultimately by favouring a better interaction and communication between the technical teams.

Many important issues within the project resulted from a lack of consistency in the data common to all teams. The floor-space and population figures were not aligned among all teams and the phasing of the project and which land use schedule was to be used for reporting was not always known nor correctly interpreted by all teams in the same way.

Other important issues resulted from a misunderstanding between technical teams. The waste, water and logistics teams assumed that the electricity needed to power their infrastructure could be provided by the zero carbon combined heat and power (CHP) plant without any difficulty, whereas the energy supply team had sized their plant based on the heat and electricity demand related to buildings only and could not afford to increase the production of electricity without sacrificing the efficiency of the CHP plant. The energy demand from the public realm (e.g. street-lighting) had not been considered by any of the teams; its supply had therefore not been covered by the CHP and its impact had not been included in the aspirational target of supplying all the energy the site needs with renewable energy.

After the first iteration of the IRM model more than fifty issues had been recorded in an "issues log"; almost all of these had been solved by the second iteration allowing teams to respond to these issues early enough within the project.

3.3 The IRM model – a reporting tool for sustainability appraisal

The IRM team reported on 11 sustainability objectives and more than thirty quantitative KPIs ranging from energy, waste, water, transport, GHG emissions and air pollution to job creation, proximity to parks and bus stops, increase in habitat for biodiversity and flood risk.

A consistent business as usual (BaU) scenario, was developed with the technical teams and its corresponding KPIs were calculated with the IRM model to serve as baseline targets for later comparison. With the data relevant to the teams' strategies introduced into the IRM model a clear list of quantified KPIs with numerical values was made available to the teams, highlighting which targets were met, which were not and how far apart they were. This helped in assessing the advantages and disadvantages of proposed technologies (CHP, vacuum waste management systems, water recovery technologies, etc.) We also developed a quality assessment of the data provided by the technical teams at each iteration, thereby helping them improve this by the second iteration.

The integrated approach to sustainability, the availability of quantified values for KPIs, the consistency in developing a BaU scenario, the documentation of assumptions made by technical teams and the quality assessment of the data they were working with served as valuable assets for an evidence-based reporting of the performance of the master-plan. This is most useful information for the technical teams involved wanting to improve their output, for the client wanting to sell the added-value of their product to potential buyers and to the public in general, but also for regulatory bodies that will want to check the performance of the project before giving planning permission.

4. Conclusion

The IRM model offers a novel approach to the integration of sustainability into the master-planning of urban design projects.

Already existing sustainability appraisals (SA/SEA) provide a well defined framework that we extend by associating quantitative key performance indicators to each sustainability objective.

The IRM model is capable of calculating numerical values of these KPIs based on data provided by the variety of technical teams working on the master-plan's different work streams.

The input capture templates of the IRM model have been developed in collaboration with these technical teams. They are therefore well adapted to the teams' models and to the information available at different phases of the master-planning process.

The IRM team informs itself about the details of each technical team's strategies and thereby acquires an overall view of the global strategy and unique insight into the interdependencies of individual strategies. This puts it in an ideal position to check whether team strategies are well aligned and to inform teams on the possibilities for better integration of their strategies.

Although the IRM model has only been used for the design of new developments it can be used unchanged for the regeneration or the monitoring of already existing urban landscapes provided it is given the necessary information.

Future planned improvements of the IRM model include the integration of the cost assessment of the construction, operation and destruction of the urban development and consideration of the embodied energy of the materials used.

5. Acknowledgements

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6. References

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