A Real Options Analysis of Urban Regeneration; The option of when to invest and its effect on providing utilities infrastructure

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Abstract:
Regeneration projects are essentially large scale refurbishment interventions aimed at improving the land-value/rents of a private development and associated public space. The typical method of valuing these property developments is the net present value (NPV) approach, which can undervalue the flexibility of investment decisions. This is particularly germane with regard to the role of utilities infrastructure in regeneration projects, where future uncertainty surrounding expected income plays a role in their business case. Real option theory, well known but seldom used by practitioners, is used here to assess the value of the option to defer investment in a district heating network due to future uncertainties surrounding the price at which gas will be sold at by competitors. This paper is a first try at demonstrating the functionality of real options as imagined to be used by property developers when considering heating infrastructure provision. In the example provided 200 two-bedroom flats will be built during a regeneration, and with the assumptions of real option theory intact, it is shown that the option of deferring investment in a district heating project is worth more than investing at current heat sale prices. There is an increase in the overall project’s marginal profit on gross development costs in the upside case (in the event of the option being called). Taken as a whole, this paper fills a gap in the use of real options in regeneration projects for considering applications of sustainable heating networks. There are many issues highlighted by this paper, such as the need for empirical validation of the results, as well as the continued development of a mathematical modelling framework.

Keywords:
District Heating, Property Development, Real Options, Regeneration.

1 Introduction
Regeneration projects are essentially large scale refurbishment interventions aimed at improving the land-value of the current area and associated public space. They are
associated with low investor demand and poor returns (Adair et al., 2003) but with regard to urban energy systems they should be considered a necessary part of the ongoing urban retrofit process.

There is a gap in the use of real options in property development. Property developers typically consider development appraisals by use of spreadsheets or commercial software, neither of which have been identified as including ‘real option theory’. Inclusion of flexible strategies into traditional development appraisals may provide a more honest understanding of the uncertainty inherent in assuming static decisions, particularly as regard to fuel and power networks in regeneration projects.

Firstly the literature for how real options could be used in development appraisals was read, and a simple example of that related to district heating investments was developed. A simple real option case study was outlined. Data from property developers or energy service companies was not available so an arbitrary example has been proposed. The inputs for the development appraisal were largely based upon Caldes figures (Caldes, 2011), the volatility of gas prices from the Department of Energy and Climate Change indices (DECC, 2011), and the two-bedroom flat areas/heat demands were obtained from the BRE Standard housing set (DECC, 2010). These parameters were not analysed over different ranges but the development figures, such as the fee breakdown, were compared for consistency with estimates obtained from interviews with estate agents. This research is U.K. based and the scope is that of a single regeneration project of 200 flats. The main limitation of this work is the lack of validating empirical data, and the assumptions surrounding the availability of a replicating portfolio.

Where there is considerable uncertainty about an important variable of interest (such as the future price of gas), there is value in assessing the value of an option such as that to defer investment. Use may be made of binomial distribution decision trees or the partial derivatives from financial option theory. In the regeneration case study of this paper, the option to defer is found to be £50,800 more valuable than the discounted profits of investing in heating mains in year one. Considering the development appraisal, marginal increases of profit due to inclusion of the heating mains are relatively small, but they are certainly not negligible.

Overall then, this paper provides a framework for future work into real options appraisal of heating infrastructure provision in regeneration developments. This is thought useful for both academics and practitioners. Firstly, a literature review and some context is provided. Thereafter the real options methodology is applied to the development of a community heating network in a regeneration scheme as explained and discussed in sections 3 and 4. Finally, conclusions on the use of real options in heating infrastructure decisions are provided.

2 Background and Literature Review

2.1 Valuations in property development

Typically in property development and construction, either simple pay-back periods or whole-life costing (the use of net present valuations) are used for valuing investment decisions (Ellingham & Fawcett, 2006). Essentially the method employed in this paper
seeks to unearth some of the hidden decisions employed in the typical net present value (NPV) calculations by use of real options. These hidden decisions reside in the use of a single scenario looking forward when plugging in numbers to a spreadsheet. There is a danger that ignoring the uncertainty inherent in property development decisions will lead to either under or over-investment (Ellingham & Fawcett, 2006). It is the uncertainty and flexibility inherent in property development that makes real options so attractive in assessing the value of planning for future uncertain alternatives, although its use by practitioners has been limited to date (Ellingham & Fawcett, 2006; Lucius, 2000). Indeed a key failing of the NPV calculation, so commonly used by developers, is its undervaluation of the flexibility of investment decisions (Hutchinson & Schulz, 2007). Many decisions in the property development process may not turn out to be irrevocable! Hence, NPV and pay-back periods are thought inadequate for use with regard to the uncertainty of future fuel/power prices (although have been used quite adequately in construction for many years).

Real option theory is used here to model the uncertainty surrounding the future heating income of the underlying fuel assets in a regeneration case study, by way of a decision tree analysis, similar but not containing all the stochastics of multi-period multiplicative processes in a binomial tree distribution (Copeland & Antikarov, 2003). The use of real options in property development is still up for debate as it cannot be confirmed that the actual numbers are accurate (Hutchinson & Schulz, 2007). Empirical data is not available, at least in the U.K., as developers may be wary of providing such commercially sensitive data to academia. There are also questions of whether all the assumptions underlying real options are found to be true in property development, such as that of a perfectly replicating portfolio (Hutchinson & Schulz, 2007; Lucius, 2000).

2.2 District heating

A district heating system comprises a central boiler plant, a distribution network of pipes, and consumption end-points. An accumulator is often used in conjunction to smooth off the differences between production and consumption, and also used as an expansion system for the distribution system (Durotan, 2011). As regards the distribution system it often competes for space underground, with the supply and return mains vying against domestic low voltage cables, telephone wire, fibre-optic cables, surface water sewers, water mains, foul water sewers, water mains for fire hydrants, gas mains, and street lighting cables. Community heating is used here as a placeholder for small district heating schemes, perhaps a more correct definition when describing shared heating along streets.

2.3 Literature Review

Real options valuations have been made use of by academics for at least 30 years and typically values the ‘real world’ option of waiting to decide whether to invest in a future time period (Lucius, 2000; Ott, 2002; Sundaresan, 2000). Real options, in terms of managerial options at least, can be ascribed as those options of (Brach, 2003): Waiting to invest, abandonment, changing scale, switching, growing, and compounding an option.

The option to allow for architectural and operational flexibility as regard future demand is relevant for heating networks, and Monte Carlo simulation is used elsewhere to assess
both such flexibility for an offshore petroleum project (Lin et al., 2009). Related to this flexibility is the option to upgrade waste heat by means of heat pumps, assessed for the potential regeneration of a housing area next to a pharmaceutical plant in Delft (Ajah et al., 2007). Alternate scenarios are assessed with regards to varying piping lengths in a district heating scheme for new build low energy houses (Olsen et al., 2008), but these alternatives do not discuss future options. A real options method is also proposed for the strategy related to when a mechanical cooling system should be installed with respect to future climate uncertainty (Greden et al., 2006), and an ‘American call option’ model is applied to the heat savings expected from investments in refurbishment of flat envelopes connected to a district heating scheme in Prague (Hajek, 2009).

With regard to the use of real options valuation in capital budgeting for investments in district heating network capacity, Kienzle & Andersson (2009) consider the value of flexible fuel supply for a gas furnace combined heat and power (CHP) plant while Ajah & Herder (2005) discuss how real options may make an energy infrastructure designer think earlier of future variables that may infringe upon the initial design. More detailed reviews of historical use of real options in property development valuation are provided by other authors (Hutchinson & Schulz, 2007; Patel et al., 2005).

3 Real Options Case Study

3.1 Real Options Methodology

A choice is a decision to be made between two or more current alternatives. An option is the possibility of making that choice now or a future date. Options give the right, but not the obligation, to take a particular decision in the future (de Neufville et al., 2008). They are not a bet, as a payment is not being forced due to future performance. They use financial modelling to value the option to postpone a current choice in the face of future uncertainty directly related to that choice. Real options have been around since before the time of Aristotle (Copeland & Keenan, 1998) but the theory has been developed recently, mainly based upon financial theory (T. Copeland & Antikarov, 2003), in particular arising from the Black-Scholes option-pricing model (Black & Scholes, 1973).

Leaving financial call and put options aside, real options for property development and technical design can be described as “on” projects, centred on speeding up or deferring a project, or as real options “in” projects, where the technical design may include optimised flexibility (de Neufville et al., 2008). The case study described below is of latter type: real options “on” the community heating scheme – the option to defer the decision to invest in a community heating scheme until next year.

There is no agreement on the best form of real options valuation. It has been argued that a modern integration of the Black-Scholes algorithm (with assumptions including a replicating portfolio, arbitrage free portfolios and random walk stock prices) for public uncertainties with subjective probabilities in a binomial decision tree (Borison, 2005). The method employed below is a simple two-period analysis, thought appropriate to mirror a real world situation. The option whether to invest in heat sales based upon volatile gas prices is valued using a simple two period calculation.
It should be noted that the example here is not a sophisticated representation of the typical call options as displayed in binomial lattice and partial derivative modelling. Even so, this is thought a necessary first attempt at demonstrating the value of considering future uncertainty implicitly in the decision process applied by property developers and energy service companies.

3.2 Regeneration case study

Imagine this arbitrary yet assumed to be reasonable case: A property developer is seeking to build 200 two-bedroom flats over two years, having previously purchased the land and planning permissions. He is building these flats speculatively but would like to maintain the heat sales from the flats where possible. He is thus considering whether to invest in a community heating scheme that would be fired by natural gas and/or biogas. Based on the previous volatility of wholesale gas prices, and (assumed to be largely dependent) domestic gas prices, he has a gut feeling that the NPV of the scheme is quite sensitive to these movements. He would like to wait until the optimum time before locking in his new customers to heat prices for twenty years, but is conscious also that costs may fall. There is an implicit notion here that customers will contrast the costs of the community heating contract with the current gas prices to make their decision – perhaps this is being too generous to the captive market of new flats.

There is a further question on the developer’s mind: is it better to use the cheaper cross-linked polyethylene pipes for the 200 flats or could he invest in larger steel pipes to allow for supplying adjacent heating loads? He is mindful that the costs of the pipes can often dominate the overall cost of community heating schemes but thinks that a small rise in gas prices could allow him to gain much higher revenues from increased capacity pipelines. Also, if the flats are begun to be built without the pipelines in place, it is likely that the first batch of flats will be built with suitably large condensing gas boilers and associated gas connections. This is quite an important decision for the developer to take and he would like to put some numbers behind these options.

The land and flats are considered certain and costs remain constant, but the cost at which the developer can sell his heat at depend upon the competitors’ cost of gas, particularly where he is seeking to expand the network to existing gas customers. The volatility of gas prices, using the industrial price index as a proxy for wholesale price movements, is shown in Figure 1 between 1983 and 2010. The standard deviation, as a measure of volatility, over this period is 17.9%.
The 200 two bedroom flats have a 400 kW baseload from a combination of space heating and domestic hot water. This regeneration project also holds the potential to provide additional heat of about 300 kW baseload demand to neighbouring buildings. A developer may well choose a changeable fuel supply for their CHP system, for instance one relying on gas primarily but with sufficient biogas support to achieve the zero Carbon regulations.

With regard to the heating network in practice it is expected that a twin plastic pipe set-up of say 63 mm outer diameter would provide space heating and hot water for the flats, with an outgoing temperature of 80 – 95 °C and a return temperature of about 60 °C. A steel set-up (e.g. inner steel pipes, polyurethane foam insulation and polyethylene outer casing) would allow for increased outgoing temperatures and increased heat flow capacity such that the existing 300 kW baseload demand could also be supplied.

A financial model of both the community heating business case and the overall regeneration scheme has been built in Excel®. The development appraisal is based in part upon the Caldes Development Appraisal Software (Caldes, 2011). With respect to sizing the baseload design of the plant there are a number of methods ascribed for estimating the future annual heat load duration curves in community heating (Dotzauer, 2002; Tekla, 2011; Verbruggen, 1980). In this paper, we estimate the heating loads for the residences by use of estimated loads during six daily periods, for each of the three seasons of winter, summer and mid-season (Weber et al., 2010). The new two bedroom flats are 61 m² in plan area, with space heat and domestic hot water demand equal to
that of the BRE Standard Homes Set (DECC, 2010). This gives a peak heat load of just under 4 kW per flat. The annual heat duration curve for 200 flats is shown in Figure 2, and was constructed using a diversity reduction factor of 10% followed by a 5% increase for heat distribution losses. The demand duration curve calculated for this profile allocates the lower two quartiles of the peak load to 85% of the total demand.

![Annual heat load duration curve for 200 two-bedroom flats](image)

Figure 2 Annual heat load duration curve for 200 two-bedroom flats

The main assumptions in this model are as follows:

- All existing mains and existing buildings are demolished prior to work on the regeneration commencing. The new mains will be installed alongside other services underground.
- Heat flow of the community heating network is designed for base load (as opposed to peak load design for higher and more continuous heat demand (RETScreen, 2005)).
- The wholesale cost of fuel is at £0.02/kWh (Ofgem, 2011). This cost is considered constant, as when the price of gas rises, the developer switches to a biogas source at equally competitive prices.
- The heat sales are sold at 10% less than the natural gas price. Competitors pricing of heat (from gas) is £0.046/kWh in year one (Ofgem, 2011). The pricing of heat, current unregulated in the U.K., is assumed constant through locked-in heat sales by means of monopolised 20 year contracts to the customers.
The above points infer that if the price of gas rises, the developer can make more money by switching to a competitive biogas or biomass supply. Whilst the supply of bio-fuel is dependent somewhat on attributes such as moisture content and location, it is assumed that biomass prices are generally at a par with gas prices (Biomass Energy Centre, 2011; Mott MacDonald, 2010), although their historical volatility has not been investigated here.

4 Findings and Discussion

The real option in this regeneration case study is that of investing now in community heating, at a heat sales price of £0.046/kWh, or waiting one year to potentially act upon upside sales prices of £0.054/kWh or downside prices of £0.039/kWh. These fluctuations are based upon an annual volatility of 17.9% volatility as shown in Figure 1. The upside and downside are considered equally likely. The real option then is does the developer wait until the likely price changes to invest in a community heating mains, or does he invest now? The developer thus has the choice to invest in steel or plastic heating mains now, or the option to invest (or not) in either pipeline design in one year’s time.

All civils, supply, installation, operational and variable costs are considered constant, as well as the debt servicing (a 6% loan for 20 years). The plastic piping design would be to supply the 200 flats at a baseload design load of 400 kWth (e.g. through a GE Jenbacher type 2 costing ~£450,000 for full installation, oil, heat recovery, enclosure and interfaces (Clarke Energy/GE, 2011)). The cost of plastic pipelines is estimated at £500/m (assumed for a length of 750 m). The steel piping design is assumed for higher baseload design – that of 700 kWth, for an assumed 200 flats but also for connection to a similar existing baseload. The pipeline design consists of 750 m of steel mains at £1000/m and 500 m of plastic pipelines at £500/m. In general, the PEX medium is considered cheaper for smaller diameters and loads of less than about 500 kW (IEA, 1999).

If the developer invests in the community heating network at today’s prices, he would build the plastic pipeline design and receive a return of 11.4% on the initial capital expenditure, for a total NPV of £94,200 (at a discount rate of 10% over twenty years of heat sales with concomitant maintenance, wholesale fuel costs and debt servicing). On the other hand, if the developer waits until next year, on the upside he would make a NPV of £233,000 from developing the steel pipeline option, but on the downside he would make a NPV of £5,960 from developing the plastic pipeline option. Such a small NPV considering the initial capital costs of £895,000 would probably inhibit investment in the plastic option in year 2. This is shown in Figure 3.

It is an easy decision to invest in the alternatives of the steel and plastic distribution networks today, with plastic providing a higher NPV, and the future alternatives are as uncomplicated to decide between. However, the key question is when to invest – what is the value of the option to defer investment in community heating? Is it better to secure a NPV of £67,050 now or is it better to use a (call) option to decide in the future when the profit of future cashflow might be £5,960 or £233,000? This query is illustrated in Figure 4.
Real option theory uses a theory that a replicating portfolio may be built up to mirror the expected costs and future profits. Here we say that an amount of money $y$ may be borrowed for one year at a risk free rate of 6.5% to construct a portfolio based upon a liquid asset. It should be noted that the option value is quite sensitive to the risk free rate assumed. The liquid asset in this case is the price of sold gas, initially at £0.046/kWh and then either falling or rising to £0.054/kWh or £0.039/kWh. The asset to be held then is secure contracts of heat sales in $x$ units of kWh. To find the value of the portfolio we solve simultaneous equations 1 and 2:

\[ 0.054x + 1.065y = 232,899 \]  
\[ 0.039x + 1.065y = 5,960 \]

The solution to these equations gives $x = 14,800$ MWh and $y = 538,000$. The value of the option today is thus £145,000. This £145 k is the value of the liquid heat sales at today’s prices less the price of the money borrowed. Given then that the value of the
option outweighs the expected profit from today’s decision, it is prudent for the
developer to delay the decision until a future date. The premium of waiting is given by
the value of the option less the profit from today’s choice (£145 k - £94.2 k = £50.8 k).

In finance the option to install a community heating network at a later date would be
called an American call option, and the price would be paid to a suitable party, but as
the developer already owns the land, there is no need for him to pay for the right to
develop at a future date (aside from the possibility of obtaining planning permission for
the welding of the steel pipes and ripping up some ground). The ownership of the land
confers embedded options (Ellingham & Fawcett, 2006).

Turning back then to the overall development of the 200 flats. The effects on the total
proceeds and profit on gross development costs of each permutation are shown in Table
1. It can be seen that there is a marginal change in profit of between 0 – 4.4% which
could be used to change the developer’s mind on the regeneration’s heating provision
prior to the design stages. Nonetheless, the expected changes could be considered small,
and it is more likely that a developer will have a risk-averse attitude to utilities
provision in general (ARUP, 2010).

<table>
<thead>
<tr>
<th></th>
<th>No community heating</th>
<th>Plastic pipes installed in year one</th>
<th>Option to wait until next year is not used</th>
<th>Option to wait until next year is used - upside</th>
<th>Option to wait until next year is used - downside</th>
</tr>
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<tbody>
<tr>
<td>Total proceeds (£ mn)</td>
<td>26.4</td>
<td>26.5</td>
<td>26.4</td>
<td>26.6</td>
<td>26.4</td>
</tr>
<tr>
<td>Profit on gross development cost (%)</td>
<td>25.0%</td>
<td>25.5%</td>
<td>25.0%</td>
<td>26.1%</td>
<td>25.1%</td>
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5 Conclusions and Further Research

This paper sought to assess a well-known financial planning methodology as applied to
a regeneration scheme (which is in essence a large scale retrofit job). That methodology,
real options, has been used by academics for at least three decades, but has yet to reach
the cumulative rate of adoption by practitioners required for widespread penetration (It
seems not even to have reached early adopters (Rogers, 2003) as measured by available
empirical studies!). Here, there is an attempt to demonstrate the usefulness of real
options as employed in heating network investments. Where there is considerable
uncertainty about an important variable of interest (such as the future price of gas), there
is value in assessing the value of an option such as that to defer investment. In the
arbitrary example given, with assumptions of perfectly replicating portfolios aside, the
option to defer is found to be more valuable than investing straight-away. The marginal
increases of profit over the entire project may be considered small, depending on how
tightly squeezed the developer’s funding is (and presumably on their attitude to
increased negotiations with energy service companies (ESCOs)/distribution operators),
but they are certainly not negligible.
Overall then, this paper provides a framework for future work into real options appraisal of heating infrastructure provision in regeneration developments. Future work will be expected to continue on from this framework, particularly in the evolution of a more robust mathematical modelling tool and also that of the inclusion of historically available data from developers, utilities and ESCOs such that these conclusions may be empirically validated. The use of real option theory to assess future expansion of valved connections is another future topic of interest to the authors – the use of real options to value design flexibility in community heating projects.

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7 References

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