

Investing in flexibility: the lifecycle options approach

William Fawcett

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william.fawcett@carltd.com

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Investing in flexibility: the lifecycle options approach

William Fawcett MA PhD RIBA

Chadwick Fellow in Architecture, Pembroke College, Cambridge
Director, Cambridge Architectural Research Ltd

wf223@cam.ac.uk

william.fawcett@carltd.com

Environmental flexibility

There is common agreement about the desirability of physical environments that can accommodate growth and change. If future growth and change could be predicted it would present a challenging technical problem but one that would be, in principle, capable of finely tuned solutions. However, growth and change cannot be predicted, which is why flexibility is sought [1].

In the absence of credible predictions, people have relied on judgment (educated guesswork) when designing and investing in flexible environments for growth and change. There are two ways in which this could lead to poor outcomes:

- Under-provision for flexibility, leading to future problems that could have been avoided if there had been better provision for growth and change
- Over-provision for flexibility, when provision is made for anticipated future growth and change, but not used.

Under-provision for flexibility is seen in every urban plan where a street layout scaled for a small settlement survives growth into a large city, creating congestion that is almost impossible to overcome,

The lifecycle options approach introduces a new and rigorous way of defining, evaluating and quantifying environmental flexibility or adaptability.

except by drastic surgery like Haussmann's in nineteenth century Paris. Could the need for flexibility have been anticipated? Perhaps not in mediaeval Paris, but London rebuilt on its mediaeval plan after the Great Fire of 1666, despite the forward-looking plans prepared by Wren, Hooke and others.

A classic example of over-provision for flexibility is the Free University of Berlin by Candilis Josic Woods. Won in competition in 1963 and built in 1967-74, it is an indeterminate two-storey network (Figs.1, 2). The architects sought 'a tentative use of a minimum structuring system where individual and group may determine desirable relationships' (Joedicke, 1968). In their design concept, 'The need for the building to be adaptable to different work programmes has been dealt with through a flexible system "in the four dimensions". ... So a totally industrialized flexible constructional system has been adopted as the standard for this building. ... Entire blocks of the building can be dismantled and put up again elsewhere' (CJW, 1975). The building was a disaster. There was physical disintegration, institutional collapse and vandalism (Bensing, 2005). By the 1990s a major refurbishment was required. Comparison of the plans in 1974 and post-refurbishment show that the building envelope did not move and the main internal alteration was the division of larger spaces into small offices – which could be done in studwork without the totally flexible construction system. It seems that the architects drastically over-valued the excessive (as it turned out) provision of physical interchangeability.

There are many examples of mismatches between investment in flexibility and the change that actually happens. To identify efficient strategies for environmental flexibility, minimising the risk of under- and over-provision, a more rigorous approach is needed.

Lifecycle options

Over the last ten years or so a proposal for transforming environmental flexibility into a well-defined and quantifiable attribute has been developed in Cambridge, UK, based around the core concept of 'lifecycle options' [2]. The research began with a study of evaluation tools for the sustainable refurbishment of existing buildings: designers come up with many ingenious ideas – but which ideas are best? Evaluating sustainability requires a long-term perspective, which should be provided by whole-life costing. But current methods of whole-life costing assume that the future can be predicted, an impossible precondition. The research developed into a new approach to whole-life costing that acknowledges future uncertainty, and favours flexible strategies that can respond to unfolding events.

In this approach, a lifecycle option is a feature of a design or plan that makes it possible for new decisions to be made in the future. A simple example: if the future size of a hospital, university or factory is uncertain, build for current requirements and retain open space into which the buildings could be expanded. The retention of open space creates the lifecycle option to expand, which has flexibility value even though it is not known when, if ever, the expansion will be carried out. Lifecycle options transfer decision-making from



Figure 1 The Free University, Berlin, under construction in 1970 (Candilis Josic Woods, architects). A complicated kit-of-parts construction system provided opportunities for reconfiguration that were never used.



Figure 2 The bland interior of the Free University, Berlin, that resulted from a uniform, indeterminate and supposedly flexible design strategy. As it turned out, hardly anything was moved. (photo David Heath, 2009)

people in the present to people in the future who will know more about the changing state of the world.

All existing propositions about environmental flexibility can be restated in lifecycle options terms; for example, the lifecycle option of retaining land for future expansion is seen in every masterplan where 'phase two' growth is indicated with arrows and dotted lines. There are two reasons for adopting the lifecycle options framework. First, diverse and apparently disconnected mechanisms for providing flexibility, for example, managerial and physical strategies, can be unified in a consistent framework; and more importantly, the lifecycle options framework gives a way of measuring and putting a value on flexibility, which up to now has been out of reach. When the *value* of a flexible project incorporating lifecycle options is quantified, it can be compared to the *cost* of providing the options – if value exceeds cost it is worth investing in the flexible project, otherwise not. By valuing lifecycle options the risk of under- or over-provision for flexibility is minimised.

There are many kinds of lifecycle option. Some are embedded options: they exist even when they are not recognised. For example, a suburban bungalow with a large garden might be sold for a higher price than its owners expected, because they did not realise that they held the option to demolish the bungalow and develop a block of flats. Overlooking option value leads to incorrect valuation – usually under-valuation.

Other lifecycle options are acquired by some deliberate action. For example, a parcel of land without road access to a highway cannot be developed for housing, but if its owner buys a strip of land that is wide enough for an access road, he creates the option to develop the landlocked parcel. The increased value due to the development option must exceed the price paid for the access strip, or the deal wouldn't go ahead.

Lifecycle options can be destroyed as well as created. For example, if a Victorian warehouse on a city centre site is declared a historic monument and protected from demolition, the option to redevelop the site is destroyed. The loss of the option reduces the value of the warehouse, or more accurately the value of the land on which it sits.

Environmental value is affected by other people's lifecycle options. One reason why tenants buy the freehold of the house they are renting is to eliminate the landlord's option to terminate the tenancy. An option was one factor when the architect Sir Albert Richardson and his wife were house-hunting in 1909: 'Cavendish house in the London Road, St Albans, happened to be on a lease with the option to purchase and they took it because of its attractive front facade with Gothick sash windows' (Houfe, 1980).

When an environment has embedded lifecycle options that are unrecognised they still exist, but there are two problems. First, lifecycle options contribute to environmental value, so if they are overlooked the environment may be undervalued. Second, unrecognised lifecycle options may be inadvertently destroyed. For example, when Victoriana was out of fashion many ornate shopfronts were boxed out or removed; boxing out retained the lifecycle option to reinstate when Victoriana came back into fashion – as it now has – but removal destroyed this option. When removing Victoriana, the option to reinstate was ignored or assumed

to be of negligible value, but the cycle of fashion is so inexorable that boxing did have positive option value.

Lifecycle options can explain phenomena that are otherwise puzzling; for example, why are valuable city centre sites used for car-parking (Fig.3)? Because the property owners believe that it is more valuable to retain the option to develop in the future than to proceed with current development in unfavourable market conditions. The owners rent the space as a parking lot and retain the lifecycle option to develop when the market changes. An option-holder can always choose whether it is more advantageous to exercise the option or retain it for possible future exercise – until the option expires.

The principles of lifecycle options are set out in the book *New Generation Whole-life Costing* (Ellingham & Fawcett, 2006); many examples in the book are at building scale but the ideas are equally applicable at urban scale.

The real options paradigm

Lifecycle options are based on a direct analogy with financial options. Financial options have a long and controversial history, and only became fully accepted with the publication in 1973 of the revolutionary Black-Scholes equation for establishing the fair price for an option [3]. Options are now an integral part of financial trading and were implicated in the recent financial crisis, but as Akerlof and Shiller note, ‘...there are two sides to creative finance: it may have gotten us into this crisis, but its genius may also get us out of it’ (2009, p.92).

In a financial option, a deal is struck to buy or sell financial commodities at an agreed price within a specified time, but the option holder can choose whether or not to complete the transaction. The option holder has to buy this option contract, usually for a much smaller sum than the transaction itself. The option holder exercises the option and completes the transaction if it is financially advantageous to do so (the option is ‘in the money’), otherwise it is allowed to lapse (the option is ‘out of the money’) when the premium paid for the option is lost. At the time when the option contract is drawn up, it is uncertain whether the option will turn out to be ‘in the money’ or ‘out of the money’ (Brealey *et al*, 2007, explain financial options).

The two basic forms of financial option are the ‘call’ and the ‘put’ – options to buy and options to sell.

A *call* option confers the right but not the obligation to buy an asset at a specified price, within a given timescale. If the market price of the asset rises above the specified price the option is ‘in the money’ and is exercised; if the market price remains below the specified price the option stays ‘out of the money’, so it expires unexercised and the premium is lost. If the option is exercised, the difference between the market price and the exercise price is profit for the option-holder

A *put* option is the mirror-image of a call. It confers the right but not the obligation to sell an asset at a specified price, within a given timescale. If the market price of the asset drops below the specified price the



Figure 3 High-value city centre sites in Toronto in low-value car-parking use: the sites' value comes from the lifecycle option to develop when the market for office development improves, not from car-parking income.

option is 'in the money' and is exercised; if the market price remains above the specified price the option stays 'out of the money', so it expires unexercised and the premium is lost. If the option is exercised, the difference between the market price and the exercise price is profit for the option-holder.

When options ideas are used in business rather than financial markets, they are called real options (Mun, 2006). Real options are encountered in the assembly of sites for the interwar New York skyscrapers, two generations before the Black-Scholes equation: 'Keeping the scope of their plans secret so as to protect against "hold-outs", brokers would approach owners of various plots to arrange for [call] options in the names of different companies' (Willis, 1995, p.160). If options could be successfully acquired for all the plots forming a skyscraper site, they would be 'in the money' and exercised so that redevelopment could proceed; if the whole site could not be assembled, the options that had been acquired would be 'out of the money' and allowed to lapse.

All lifecycle options give value to the option-holder because they are only exercised if it is advantageous to so, but option value varies greatly from case to case and depends on the following factors:

1. *The amount of uncertainty* In a situation with no uncertainty about the future, lifecycle options are pointless and valueless. As the amount of uncertainty about the future increases, the value of lifecycle options increases as well.
2. *Duration of the option* Some lifecycle options are effectively perpetual, like a property owner's option to sell. Others have a fixed term; for example, planning consents in the UK are usually valid for five years – if the option to develop is not exercised within that period it lapses. The longer the life of an option, the higher its value.
3. *The probability of exercising the option* Every option has a trigger point, and if this point is reached it will be exercised, but the probability of reaching the trigger point varies. A lifecycle option has nil value to an investor who does not believe that it could ever be exercised. Compare, for example, two lifecycle options embedded in a coal-fired power station: there is a higher probability of exercising the option to switch fuels from coal to oil, than of exercising the option to switch use from power station to art gallery – although both options were successively exercised at the Bankside Power Station in London, which is now the Tate Modern art gallery. The greater the probability of exercising a lifecycle option, the higher its value.
4. *The time to exercise* The value of lifecycle options is derived from future benefits, and the phenomenon of time preference tells us that people attach more value to a benefit that is received today compared to the same benefit received a year from now, and much more than if it is received far in the future. People have different intensities of time preference; a Cambridge college, for example, recently bought the option to acquire a river-front site in 125 years time; the college was founded over 700 years ago and took a long-term view, but even so the option would have been more valuable with an earlier exercise date. The earlier the probable exercise date of a lifecycle option, the higher its value.

5. *The cost of exercising the option* Some options can be exercised at no cost; for example, if a building is repainted every five years, there is a no cost option to change the colour every five years. Most options incur a cost penalty when they are exercised; compare, for example, two technologies that provide the option to move non-structural partitions in a building: if the partitions are made of plastered blockwork it is slow, disruptive and expensive to exercise the option, but if they are made of demountable panels it is much quicker and cheaper to exercise the option – so people are prepared to pay more for demountable partitions. The lower the cost of exercising a lifecycle option, the higher its value.
6. *The resulting benefit* The value of a lifecycle option depends on the scale of the benefit that would be derived from exercising it. For example, the benefit derived from exercising an option to change colour when repainting a building is modest. On the other hand, the benefit from exercising an option to extend the building stock of a university is very great – without it the university's development might be strangled. This is why the new universities founded in the UK in the 1960s had large sites of at least 80 hectares, even though start-up student numbers were tiny: the cost of acquiring and retaining empty land bought the valuable option to expand. The value of a lifecycle option increases with the scale of the benefit that would result from exercising it.

These principles can be applied qualitatively when evaluating the lifecycle options or flexibility – indeed ‘options thinking’ is perhaps a greater contribution to good decision-making than quantification. However, quantification of lifecycle options, and hence flexibility, is also possible in many situations.

Quantifying lifecycle option value

The range of possible lifecycle options is unlimited, but they fall into a small three main types:

- *Lifecycle options to expand/upgrade*: for example, when specifying the infrastructure for a new urban extension, providing generous infrastructure capacity in relation to initial needs will create the lifecycle option to add further development. This corresponds to a typical strategy for environmental flexibility – the provision of redundancy or overcapacity.
- *Lifecycle options to switch*: for example, many non-prime office buildings in London have been changed to residential use – the office buildings had an embedded lifecycle option to switch use, even though it may not have been an objective in the original design. There are also acquired switch options, for example, when a high price dual-fuel boiler is specified because it creates the option to switch fuels in response to future changes in fuel costs and supplies. Provision for changing the use of a building, even when there is no physical alteration, is also an example of a switch option.
- *Lifecycle options to contract/abandon*: for example, most multi-phase masterplans are changed or abandoned before completion, so there is merit in devising plans that work well at each stage, even if later stages never happen. This is discussed by Rosenhead *et al* (1972), although they do not use options terminology, referring to the concept of *robust* plans.

Lifecycle options can derive from physical characteristics of the environment, such as non-structural partitions that are easier to relocate, and they can also derive from social conventions or legal/contractual arrangements, such as planning rules that permit change of use.

The ways of calculating lifecycle option value are similar for all types. The sophisticated techniques developed for valuing financial options would be the natural starting point, but in fact they are of limited value. There are three reasons: first, financial commodities are interchangeable and transactions repeatable, whereas all environments have unique characteristics; second, there are large and accurate databases of past financial transactions, providing input data for advanced mathematical modelling, whereas historic data about environments is patchy and vague; and third, the financial industry employs many high-powered mathematicians, but there are few working in construction or the environment.

As a result, lifecycle options are usually valued with relatively straightforward simulation exercises, as in the examples in *New Generation Whole-life Costing* (Ellingham & Fawcett, 2006).

The following example of a lifecycle option to expand/upgrade is based on a viaduct over a valley in Toronto that was built in 1919. (Fig.4) The viaduct was initially required for road traffic, but the city was aware that a new railway commuter line might be built later along the same route. The new viaduct could be built for road traffic only, or with a road and railway deck, or with a roadway and the lifecycle option to add a future railway deck. Thus the city had three viaduct alternatives [4]:

- A. road-only viaduct, costing \$30m (all prices adjusted to today's values)
- B. viaduct with an upper roadway and a railway on a lower deck, costing \$38m
- C. viaduct with an upper roadway and the lifecycle option to add a railway on a lower deck, costing \$34m – the option adding \$4m to the cost of a road-only bridge.

Additional data:

- exercise cost of adding railway, if lifecycle option acquired: \$6m
- cost of building separate railway viaduct: \$20m
- probability and timing of a new commuter line: 60% probability within 50 years
- discount rate to reflect time preference: 2.75% per year (a low rate for public investment).

The uncertain future as viewed from 1919 was simulated with 500 scenarios, in each of which the year of constructing the new commuter line, or of not constructing it within 50 years, was generated using random numbers; in Alternative C this would be the date of exercising the lifecycle option to add the railway to the viaduct, and in Alternative A it would be the date of building a new railway viaduct. The three viaduct alternatives were evaluated for all of the 500 scenarios, and the costs were discounted back to 1919 using the 2.75% per annum discount rate, giving the present value in 1919 when the decision

between the alternatives had to be made. The averages of the 500 simulations are shown in the table below. Alternative C, with the lifecycle option to upgrade the viaduct, performs best in the simulation.

	Alternative A: road viaduct only	Alternative B: road and railway viaduct	Alternative C: road viaduct with lifecycle option to add railway
Initial cost in 1919	\$30m	£38m	\$34m
Action when and if commuter line constructed	Build new railway viaduct, costing \$20m	No action required	Exercise option to add railway, costing \$6m
Present value of cost of action, discounted to 1919 – average of 500 scenarios	\$7.4m	0	\$2.2m
Total	\$37.4m	\$38m	\$36.2m

The viaduct was in fact built with the lifecycle option to add a railway (Alternative C), but the Great Depression and World War II – unexpected events! – intervened and the commuter line was not constructed until 1966, 47 years after the option had been acquired. Had the city known in 1919 that the commuter line would be constructed in 1966 they would have gone for the cheapest viaduct with a roadway only (Alternative A) – but with the uncertain knowledge that was actually available in 1919 their decision to invest in the lifecycle option was rational.

It is important to realise that all decisions about lifecycle options and flexibility have to be made with present knowledge, despite the fact that it is incomplete. If better knowledge were available, it would be used. Decision-makers know that later events will supersede their knowledge but this does not help them at all – except to reinforce the wisdom of providing lifecycle options.

Envisaging possible activity states

In the viaduct example the flexible strategy and the other strategies were evaluated with reference to a set of scenarios that reflected the decision-makers’ state of knowledge about possible future events. If a different set of scenarios had been used, the strategies would have been valued differently. Is there a paradox? – flexible strategies are sought because it is impossible to predict the future, but the evaluation of flexibility requires that possible futures are specified.

It is not a paradox, but it demonstrates something about flexibility that is not always acknowledged. Environmental flexibility cannot be added in ever-increasing quantities until eventually a universally flexible environment is achieved – one that could accommodate all possible future demands of any kind. This is fantasy: there is no such thing as a universally flexibility environment.

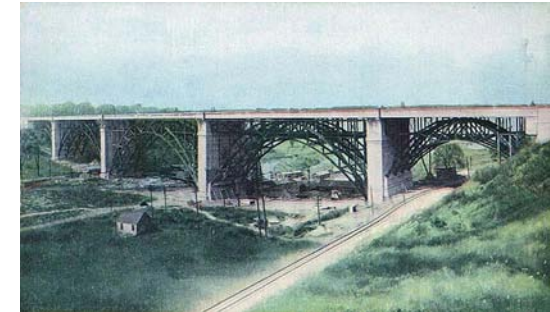


Figure 4 The viaduct in Toronto as built (above) with a road deck and the option of adding a railway on a lower deck.

The viaduct today after the exercise of the option (below), with a commuter train on the lower railway deck. (photos from internet)



Every environment can accommodate a range of activity states. Some environments are tightly adapted for a narrow range of activities, for example, a nuclear power station site, and others can be used in many different ways, for example, a gridded city like Manhattan. Environments with a wider range of possible uses are certainly more flexible, but each environment is flexible in a specific way. Manhattan is much more flexible than a nuclear power station site, but it cannot accommodate a nuclear power station.

Thus, when environmental flexibility is sought, one has to be able to answer the question – what is the flexibility for? One might imagine that flexibility makes the question irrelevant, but this is incorrect. The question is answered by defining by a set of possible activity states. Not states of configuration of the physical environment – a static environment may be able to accommodate all relevant activity states without physical change.

If a design with a changeable physical environment is put forward as a strategy for flexibility without an explicit statement about the future activity states that it accommodates, then the design implicitly defines its flexibility by the activity states that it can actually accommodate – and the flexibility may turn out to be of limited value. This seems to have been the case at the Free University, Berlin: the physical fabric could be changed, but it was not clear what activity states would require the physical change, and in fact there was very little physical change.

The ensemble of possible activity states

In some cases the question ‘what is the flexibility for?’ can be answered with a list of the relevant activity states; for example, a family house might require flexibility to accommodate the successive stages of a family with young children, older children, and then elderly parents. But broader ranges of activity states can be defined by possible attribute values, not an exhaustive list; for example, a hospital accident and emergency centre might require flexibility to cope with demand between 100 and 200 patients per day and a male-female ratio between 60% and 40%. From the specified attribute ranges future scenarios can be simulated, as in the 500 scenarios for the viaduct example.

This is getting close to what Wiener (1954) termed the Gibbsian approach, after the Yale physicist J W Gibbs (1839-1903): ‘Gibbs’s innovation was to consider not one world, but all the worlds that are possible answers to a limited set of questions concerning our environment.’ The answers are termed the ensemble of possible states of the system. ‘If all objects are given, then at the same time all possible states of affairs are also given,’ as Wittgenstein observed (1921, §2.0124).

Specifying the ensemble of all possible activity states may seem over-ambitious, but the level of description can exclude unnecessary detail. Take a pared-down but important example: the ways that a population of people can divide into separate groups. This is important for matching the physical environment to activities

– when visiting a cinema a population is grouped together in a single space, but at a hotel a population is divided into sub-groups requiring many smaller spaces. The possible groupings of a population can be enumerated: for a population of four people there are five groupings (Fig.4b), and for a population of eight people there are 22; for larger populations the numbers rise quickly (Fawcett, 1979b). If the population is made up of distinct individuals, the number of ways that they can arrange themselves into a particular pattern of grouping can also be enumerated: these can be called the microstates associated with the grouping (Fig.4c). There is wide variation in the number of microstates associated with different groupings; if the individuals in a population were able join groups in an unconstrained way, one would imagine that each microstate would have equal probability of occurrence and that the groupings with most associated microstates would be more likely to occur. This means that the probable patterns of grouping in a population can be anticipated, even when there is no information about details like people’s names, age, social class, reasons for joining other individuals, etc, etc.

Following this line of reasoning, mathematical analysis predicts that the most probable groupings will follow a characteristic skewed pattern, with few very small groups, many quite small groups, and a diminishing number of groups as the size gets larger. Mathematically it is a positive Poisson distribution (Fawcett, 1979a). This theoretical result can be compared with empirical studies of free-forming groups carried out independently by James (1951, 1953). He observed regularities that matched the skewed distribution described above, and Coleman concluded that the observed groupings followed a positive Poisson distribution (Coleman & James, 1961) – a gratifying convergence of theoretical and empirical investigations. Both studies worked with highly simplified activity descriptions: choosing attributes parsimoniously is crucial for the Gibbsian approach.

Designing for activity uncertainty

How does this connect to environmental flexibility? Flexibility is sought because of uncertainty about future activity states, but the Gibbsian approach shows that we often know more about possible activities than we realise. This knowledge should be used.

Consider a worked example, about the design of a set of seminar rooms for a university department with 80 students (Fig.5). Because the sizes of seminar groups is unpredictable a flexible design is required. Simplifying the problem, suppose that seminar groups are always made up of multiples of 10 students; then there are 22 possible seminar groupings, with 4945 microstates; as before, the groupings have varying numbers of microstates, so are not equally likely to occur.

Suppose there are three alternative designs to evaluate: (A) has four moving partitions that allow it to adopt 16 (ie. 2x2x2x2) different layout configurations; (B) has a slightly larger floor area but no moving partitions; and (C) is like (B) but with just one of the fixed partition replaced with a moving partition – it

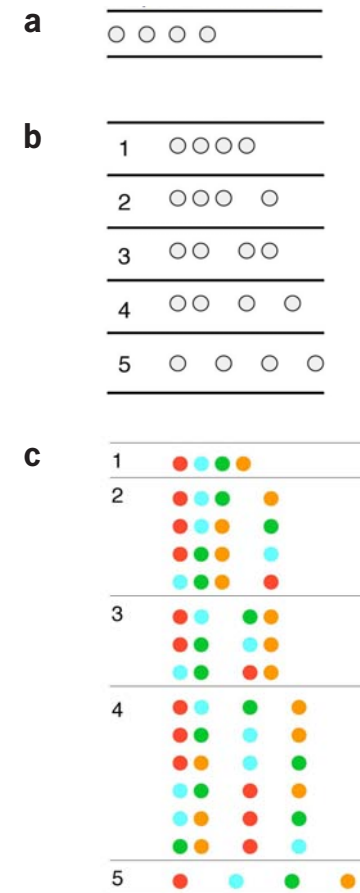


Figure 4 There is a finite number of ways that a population can divide into groups. Consider a population of four (4a). There are precisely 5 possible groupings (4b). If the members of the population are distinct individuals, it is possible to enumerate the possible ways that the individuals can form the groupings (4c).

Microstates are not evenly distributed across groupings. If all microstates are equally likely to occur, the numbers of associated microstates is a measure of each grouping’s probability of occurrence. When there is uncertainty about how a population will divide into groups, it is reasonable to expect that the groupings with the largest number of associated microstates are more likely to occur.

can adopt two layout configurations. When compared against the Gibbsian ensemble of microstates, Alternative A performs worst despite having the largest number of possible layout configurations; Alternative B performs better and Alternative C best. The results are shown in the table below:

	Alternative A:	Alternative B:	Alternative C:
Possible layout configurations	16	1	2
Possible seminar groupings accommodated (max 22)	7	3	5
Possible seminar microstates accommodated (max 4945)	1695	2660	3290

It is evident that a design which aims to provide flexibility for activity change must be evaluated by comparison with possible activities, not by counting the number of different physical configurations. Designers may find this unwelcome, as they have control over the physical environment and can expend their ingenuity on ways of increasing physical changeability. But to produce effective designs or plans they have to engage with activity uncertainty, and the Gibbsian approach makes this possible even when there is little specific data about activities. It is not tenable to argue that provision for maximum physical reconfiguration is a valid response to activity uncertainty.

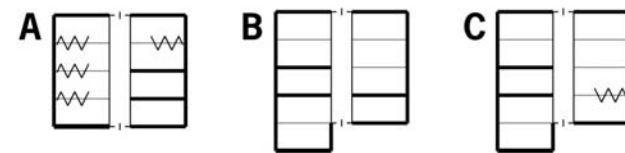
This theory was put into practice in the new building for the Faculty of English in the University of Cambridge (Allies and Morrison, architects, 2004) (Fig.6). The author proposed [5] that the sizes of seminar rooms should approximate to a positive Poisson distribution, with few very small rooms, more quite small rooms and a small number of larger rooms:

Room type and size	Number
small group/supervision room (3 people)	3
small class/seminar room (16 people)	2
class/seminar room (24 people)	2
classroom (30 people)	3
large classroom (70 people)	1
lecture room (100 people)	1

Grouping	Seminar group sizes								Microstates
1	80								1
2	70	10							8
3	60	20							28
4	60	10	10						28
5	50	30							56
6	50	20	10						168
7	50	10	10	10					56
8	40	40							35
9	40	30	10						280
10	40	20	20						210
11	40	20	10	10					420
12	40	10	10	10	10				35
13	30	30	20						280
14	30	30	10	10					280
15	30	20	20	10					1680
16	30	20	10	10	10				560
17	30	10	10	10	10	10			56
18	20	20	20	20					105
19	20	20	20	10	10				420
20	20	20	10	10	10	10			210
21	20	10	10	10	10	10	10		28
22	10	10	10	10	10	10	10	10	1
									4945

Figure 5 The 22 possible states of grouping for seminars with 80 students, when seminar sizes are in multiples of 10 students; and the associated number of seminar microstates (above).

Three alternative designs for a set of seminar rooms, where each spatial module can accommodate 10 students (below). Alternative A has eight spatial modules; Alternatives B and C have nine. The partitions between modules are fixed partitions (solid line) or movable partitions (zig-zag line).



This proposal is in contrast to the ‘modularity bias’ of many architects who assume that a set of identical rooms will be most flexible. The Poisson-derived seminar room strategy was carried out in the Faculty of English and feedback from users of the new building has been positive – so far.

Conclusions

This paper has argued that environmental flexibility for future growth and change in activities is derived from lifecycle options, and that flexible strategies must be evaluated by comparison with an ensemble of relevant activity states. It is a purely pragmatic approach that attempts to make the concept of flexibility precise, quantifiable and useful.

The history of flexibility as a design objective has been far from precise, quantifiable and useful. It has sometimes been elevated to inappropriate prominence and used to justify crushing banality or irrational extravagance. The Free University, Berlin, falls into the first category (and the banality was expensive to build); the Centre Pompidou, Paris (Piano & Rogers, architects, 1972) falls into the second, where flexibility ‘seems to have led to an overschematic solution ... It is difficult to envisage any function which would require an unimpeded fifty-metre span with a height limitation of seven metres’ (Colquhoun, 1981, pp.116-117). Neither tendency would be supported by a rational understanding of flexibility.

Even when flexibility has been pursued soberly, it has been unfocused. Lifecycle options to enhance/upgrade, to switch elements, or to contract/abandon are often encountered in the literature on design for flexibility, although the options terminology is new. For example, Weeks’s proposals of the 1960s and ’70s, such as ‘indeterminate architecture’ (1963) and ‘multi-strategy buildings’ (1969), offer a fairly comprehensive overview of what can be done by architects to create flexible environments. What has been lacking is a method for evaluating the various ideas and deciding when and where and to what extent they should be employed. Today this is possible through the use of the lifecycle options approach.

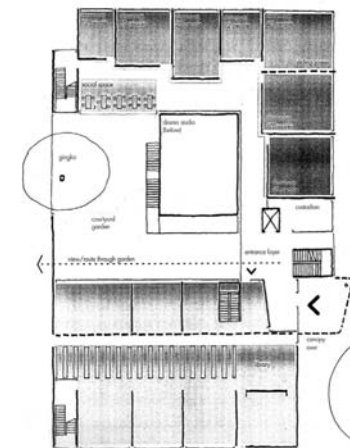
The opportunities for re-inventing the wheel in design for flexibility seem inexhaustible. The catalogue of ingenious ideas in *Flexible Housing* by Schneider and Till (2007) is depressing, partly because of the duplication of design effort, but especially because no attempt is made to test the ideas assembled so laboriously, either by simulation or by surveying the experience in use of the proposals that were built. It implies that the field is open for an on-going stream of untested ideas.

By demystifying environmental flexibility the lifecycle options approach may strip the topic of some of its fascination, but if the approach can increase the long-term value of construction investment this will be a fair exchange.



Figure 6. The sizing of seminar rooms in the new Faculty of English building in the University of Cambridge (Allies and Morrison, architects, 2004 – above) was based on an approximation to the positive Poisson distribution, to provide flexibility when there is uncertainty about the size of seminar groups.

A design study for the ground floor of the Faculty of English building (below) shows the size variation of seminar rooms. The smaller seminar rooms were distributed around the building.



Notes

- [1] In this context the words *flexibility* and *adaptability* overlap in meaning. Sometimes a distinction is drawn between the precise meanings of the two words but, confusingly, this is not done in a consistent way. In this paper flexibility is used exclusively, but the words are regarded as synonyms and the choice is arbitrary.
- [2] The original study of lifecycle options was led by Cambridge Architectural Research Ltd, supported by two grants in the UK Department of Trade & Industry's 'Partners in Innovation' programme of construction industry research, 1998-2002. Dr Kanak Patel of the Department of Land Economy in the University of Cambridge participated in the research team. The research is continuing through the European Commission-funded CILECCTA project (2009-13) – see www.cileccta.eu
- [3] The Black-Scholes equation for pricing financial options was developed by Fischer Black, Myron Scholes and Robert Merton. Scholes and Merton were awarded the Nobel Prize for Economics in 1997; Black had died in 1995. For a survey, see Boer (2002).
- [4] This example was provided by Dr Ian Ellingham; the viaduct is real but the numbers are illustrative.
- [5] The advice was part of a pre-design and briefing study carried out by Cambridge Architectural Research Ltd.

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Dr William Fawcett is an architect with experience in research, practice and consultancy. He is currently Chadwick Fellow in Architecture at Pembroke College, Cambridge, and is leading the Activity-Space Research initiative at the Martin Centre for Architectural and Urban Studies, in the University's Department of Architecture¹. This initiative is developing quantified simulation models of the use and occupancy of buildings and the built environment. He is also a director of Cambridge Architectural Research Ltd², where his areas of interest include accommodation studies and design briefing, whole-life evaluation of buildings, and conservation plans for listed buildings.

1. www.arct.cam.ac.uk
2. www.carltd.com