Analysis of Costs and Benefits of Tall Buildings

Abraham Warszawski, F.ASCE[1]

Abstract: The paper evaluates the cost-benefit parameters of tall residential buildings 10 to 40 stories high, as compared with 5 to 7 story high conventional buildings. Two viewpoints are examined: those of the developer and of the dweller. The paper explains the methodology employed in the evaluation and examines the following parameters: the costs of construction, land, financing, and risk; the costs during use; and also the intangible impacts of tall buildings on scenery, open spaces, safety, accessibility, and other factors. Conclusions are presented, and their applicability under different conditions is discussed.

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Introduction

The object of this study was to develop a method for evaluation of the advisability of erecting a tall building at a given location from the viewpoint of the various parties concerned, mainly the developer, the resident, and the municipal authority. The method is expected to aid these parties in their decision making, in evaluating the feasibility of a specific project alternative, in comparing it with other alternatives, and in identifying specific parameters that can, if attended to, make the project more attractive.

It is difficult to find an unequivocal definition of a tall building. The Council of Tall Buildings and Urban Habitat (CTBUH)—the main body compiling information and promoting the advancement of knowledge about tall buildings—defines a tall building as one whose height significantly affects the various aspects of its design, construction, and use (CTBUH 1980). The Israeli Law of Design and Building 1965 (Ministry of Interior 1965) defines as a ‘‘tall building’’ one whose upper floor level is 27 m or more above the level of its ground entrance. In residential buildings, this roughly corresponds to the height of 10 stories or more. Therefore, in this paper we will refer to the term tall building as a generic designation for buildings of 10 stories and higher.

This study is concerned with residential buildings 10 to 40 stories high. In many countries, residential buildings account for 60 to 80% of the total building output. They are more homogeneous than any other major type of building in their standardized performance needs and their resulting functional, spatial, and technological requirements. Moreover, several other types of buildings, such as hostels, nursing homes, and also to some extent offices, hospitals, schools, and so on, have similar performance specifications, and many aspects of residential acceptability apply to them too.

New construction of tall residential buildings in Israel amounts annually to about 10% of total building starts (based on floor area). Buildings of 1 to 2 stories represent about 40% and buildings of 3 to 7 stories about 50% of the total Central (2000). The share of 1 to 2 story buildings in the cities is insignificant; the vast majority are multifamily cooperatives (condominiums) of three stories or more. We will therefore focus our discussion on two groups of buildings: those of 3 to 7 stories, to which we will refer by the generic name of conventional buildings, and those of 10 to 40 stories, to which we will refer as tall buildings.

The literature on tall buildings that is pertinent to this study can be divided into several topics. One deals with the economic aspects of tall buildings; its prominent representatives are Tragenza (1972), Flanagan and Norman (1978), Newton (1982), Code (1990), Picken (1992), and Steyert (1972). The second group concerns the engineering aspects and includes the various CTBUH publications and pertinent building codes. The third group deals with the dweller's perceptions of his or her tall building [Conway (1977) and other sources, to be mentioned later in the appropriate context]. Finally, a large body of literature deals with the visual/architectural aspects of tall buildings but will not be referred to in this part of the study.

In general, the study makes a cost-benefit analysis of a tall versus a conventional building, as defined above, from the points of view of three different parties:

1. The developer, who performs the various activities essential to the realization of a building project. His or her decisions involve the nature of the building, its schedule of execution, and its sale or rental terms;
2. The dweller, who acquires or rents the building and uses it. His or her decision involves a readiness to reside in the tall building and an agreement or disagreement to pay the price for acquisition of the building and its use; and
3. The municipal authority, which represents both the residents of the tall building and all other parties that may be affected by the tall building's construction and its impact on its vicinity.

This paper concerns the major parameters of such decisions from the viewpoints of the developer and the resident; the approach of the local authority will be examined in a sequel paper.

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[1] Professor, Faculty of Civil Engineering, Technion, Israel Institute of Technology, Haifa 32000, Israel.

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Methodology

In general, the methodology of the study was to compare, from different points of view, the costs and benefits of a tall building with those of a similar but conventional building of 3 to 5 stories.

An important methodological decision involved the basis for comparison. That basis is very important when examining such tangible costs and benefits such as land, construction, operation and maintenance, and others.

Two alternative methods have been employed by other writers in the analysis of the influence of patterns of design alternatives on the cost of the relevant systems.

1. Statistical analysis of the costs associated with these alternatives in a representative sample of buildings. This approach was employed by Tragenza 1972, Flanagan and Norman 1978, Newton (1982), Code (1990), and Picken (1992).
   To produce viable results, the sample must fulfill these conditions:
   - It must include sufficient representatives of each design option to be examined (in our case, various building heights and land densities);
   - It must be reasonably consistent in terms of the performance requirements for the different items in the sample;
   - It must be large enough to smooth the different noises and focus on the differences between the parameters to be studied; and
   - All the cost information involving the sample must be available.

   These conditions make it extremely difficult to obtain such a sample, especially from the private sector, where most of these projects are initiated.
2. Experimentation with a ‘‘model’’ of a typical building having the following characteristics:
   Its main features represent a large share of the building's population in terms of its plan, functional specifications, and main systems;
   - It must represent different alternative building heights as well as their impact on the various building parameters while preserving similar performance specifications;
   - It must incorporate the service systems, which may be economically significant; and
   - All these systems of the model have to be designed and their cost estimated.

   The main difficulties of this approach, which was adopted in Styert (1972) and Warszawski (1983), are
   - Selection of a truly typical model of the particular population of buildings to be studied may not be easy in the absence of sufficient statistical data because the model is really effective only in a largely homogeneous population; and
   - Identification of the optimal alternative for each building system in each examined building height, its detailing and estimating, require a large amount of design work.

   The approach ultimately chosen in this study is a less expensive variation of the second method. Its principles are
   a. A typical model building is selected in light of the relevant published statistical data;
   b. An optimal alternative is identified for each of the several ranges of building heights. The alternative is determined in consultation with experts in the relevant engineering disciplines; and
   c. The comparative analysis focuses on the differences in the system characteristics for different building heights and their *cost differentials* from the conventional baseline.

The desirability of a *tall-building* project was examined in the light of an ‘‘objective function,’’ which indicated the value of that project to each of the interested parties (the developer, the dweller, and the municipal authority). The main independent variable was the height of the building, and the dependent variables were the costs and benefits affected by its height. Other parameters reflected various engineering, economic, and statutory features of the building environment.

The model chosen to produce the necessary parameters was based on the available statistical information on building patterns in Israel. It included a multistory building with repetitive residential floors, each comprising a main area of four dwellings, each of with an approximately 105 m^2 floor area, and a service area with an elevator landing, a staircase (or staircases), shelters, and storage space. The ‘‘service area’’ as defined in the Israel Law of Planning and Building (Ministry of Interior 1965) occupies 20–30% of the ‘‘main area’’ of the dwellings. The height of a residential story was assumed to be 3.00 m.

The main variable of the model was the number of residential stories, which varied between 3 and 5 stories for a conventional building and 10 and 40 stories for a tall building. Another variable, which was examined in the context of the cost of land, was the density imposed on the building lot, which varied between 100 dwellings per hectare [roughly a 120% floor-to-area ratio (FAR)] and 300 dwellings per hectare (400% FAR). The density, as explained later, was also assumed to be dependent to some extent on the height of the building.

The costs and benefits are defined here in their widest sense and include both tangible and intangible elements. The tangible costs and benefits can be directly assessed from their engineering parameters and market prices, while the intangibles involve any type of sacrifice or advantage that cannot be measured directly in an objective manner. Examples of intangible benefits are open space, scenery, availability of certain amenities, and so on.

The general approach to the valuation of intangibles [as in Mishan (1989) and other] is as follows:

- The economic value of an intangible benefit is the amount of money that the interested party is willing to pay for it *or* that it would agree to accept as a compensation for giving it up. Similarly, the economic value of an intangible cost is the amount of money that the affected party is willing to pay for averting it or that it would agree to receive for accepting it.
- The intangibles can be divided into those that can be measured in an objective manner though not in directly economic terms, such as open spaces or accessibility and those that can be assessed only in a subjective manner, such as aesthetic values.
- Most of the parameters examined here in the context of the developer's viewpoint are tangible. The parameters examined in the context of the dweller's viewpoint are mostly intangible, but of the objectively measurable type.

Developer's View—Principles

The developer, as noted earlier, is the party who initiates, designs, finances, erects, and sells or rents the building to dwellers. Different actors—designers, contractors, suppliers, inspectors, and others—are involved in the process, but all of them, with the exception of the local authority, are nominated and controlled by the developer.

The main objective of the developer in the project, as defined for this study, is to maximize the net present value of the project's cash flow.

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Table 1. Additional Cost of Tall Residential Buildings When Compared with 3–5 Story Conventional Buildings (in Cost per Square Meter and in Percent of Cost of Conventional Building per Square Meter)

		Height of building (floors)						
		10–19		20–30		31–40		
	System	($)	(%)	($)	(%)	($)	(%)	Reasons for additional cost
1	Structure	13	2.2	32	5.3	50	8.3	Size of core and columns[a]
2	Sanitary	6	1.0	6	1.0	6	1.0	Water tanks, pumps, vertical piping, garbage disposal[b]
3	Electrical	7	1.2	7	1.2	7	1.2	Control, announcement, emergency lighting, emergency power supply
4	Fire protection	10	1.7	35	5.8	35	5.8	Sprinklers, smoke detectors, fire-resisting doors, interdwelling and interdoor fire separation, extra staircases, pumps, water hydrants
5	Air conditioning	15	2.5	15	2.5	15	2.5	Common cooling tower
6	Elevators	4	0.7	21	4.2	35	5.0	Additional elevators, higher speeds
7	Parking	100	16.7	100	16.7	10	16.7	Mandatory underground parking
8	Exterior walls	NA	NA	NA	NA	NA	NA	Strength, precision[c]
	Total	155	25.8	215	35.8	242	40.3	

[a] Due to accumulation of vertical load in lower-floor columns and earthquake and wind horizontal forces acting on the core and possibly on peripheral columns.

[b] Pressure in the municipal water network suffices only for 4–5 stories. System of water tanks on the ground and roof levels and pumps is necessary to supply water everywhere at sufficient pressure. Water at required pressure is also required for fire protection purposes.

[c] Strength higher than in conventional buildings is required due to high wind pressure at high elevations. High precision in setting up columns and production of wall panels is essential for avoiding costly difficulties of assembling tall buildings.

The main groups of parameters for the developer's cash flow that will be examined in this context are those affecting the costs of land and the investment in building and infrastructure, as well as the income from the sale or rental of dwellings. The costs of financing and risk will also be examined in this context.

Developer's View—Cost of Construction

The height of a building affects the cost of various systems within it. The main systems examined in this context include

- Structure;
- Sanitary installation;
- Air conditioning;
- Electrical and mechanical systems;
- Fire protection;
- Interior space separators and their finish;
- Exterior walls;
- Parking; and
- Foundations.

The general method of the cost analysis employed here was explained in the section on methodology. For the analysis of the construction costs, it included these steps:

- A building described in the section on methodology was chosen as a model for purposes of comparison. The model comprised four alternative building heights, namely 3–5, 10–20, 21–30, and 31–40 floors;
- The most appropriate solution for each system and each height alternative was identified with the aid of design experts in each associated discipline; and
- The cost analysis focused on the differences between the systems in each alternative rather than on their complete design.

The main effects of the increase in building height were identified as

1. Economic benefits, mainly in the following areas:
   - The learning effect due to the repetition of certain activities on many floors of the same composition, which results in a saving of the labor input per unit. The quantitative aspects of this effect are examined in Oglesby et al. (1988); and
   - The benefits of scale in the contracts regulating the supply of various materials and systems to be used or installed in the building.
2. Additional construction requirements, resulting in extra costs, such as
   - Changes in the performance requirements for the various systems as the height of the building increases. These changes resulted either from higher exterior loads (for example, on the structure); from a stricter observation of safety precautions (for example, in fire protection); or from direct functional needs (for example, in elevators);
   - The need for more advanced equipment for the handling of materials, concrete casting, safety precautions, and labor transportation in the building;
   - Provisions for the storage of materials and tools and for support functions on several floors; and
   - Greater precision in making measurements and in execution of the work.

The final effect of building height on the different building systems was evaluated in light of the requirements laid down in the pertinent codes and regulations and of the opinion of experts. The resulting cost differentials were assessed for each system. These differentials and their main causes are summarized in Table 1.

Table 1 shows that the additional construction cost of tall buildings varies between $155 and $240 per square meter, depending on the number of floors, which amounts to 25–40% of the cost per square meter of the conventional building.

Developer's View—Cost of Land

The cost of land is a major component of the developer's cash flow that in the larger city centers of Israel may amount to 50% or more of the total project cost. The influence of the building height on the cost of land per dwelling must be examined in the context of the permitted building density. Density of residential building may be measured in terms of dwellings per hectare or in terms of the ratio between the floor area and the land area (the measurable floor area, as defined by the Israeli Central Bureau of Statistics, includes roughly all the floor area in the building enclosed by exterior walls and also the area under these walls).

The reader may also notice the distinction between (Alexander 1993):

- Net density—pertaining to these ratios in a particular building lot;
- Gross density, which includes in the denominator the total area of the neighborhood, i.e., the residential land lots, the roads, the public areas, and the areas occupied by the community services; and
- City density, which also includes in the denominator the general public areas and roads of the city, outside the residential neighborhoods.

The cost of land has to be examined for two typical cases: in one, the developer conforms his or her design to the densities prescribed in the established zoning regulations; in the other, he or she wants to change them, usually to increase the permitted density. In the first case the cost of land has already been determined and usually paid for, and will not be affected by the chosen height of the building. In the other case, the cost of land will depend on its value as affected by the requested changes.

The value of land, as used here (Real Estate 1996), refers to the price that would have been paid for the land in a fair transaction, that is, with market information fully disclosed, no pressure exerted on either side, and the price reflecting all aspects of the deal (no hidden clauses).

In general, the value of land at a given location is affected by the following factors: (Rose 1992):

- Nature of the building lot—its size, topography, and shape;
- Zoning regulations, which prescribe the density and nature of the buildings to be erected in terms of height, parking, facing, and so on;
- Environmental aspects of the location—scenery, noise, climate, and so on;
- Socioeconomic profile of population in the vicinity;
- Accessibility of major centers of commercial and cultural activity;
- Availability of community services;
- Taxes imposed on the land; and
- Supply of land in the area.

In a more specific context for this study, the value of land is determined by the profit its owner can realize from its use for a given set of the above-mentioned factors. In the case of land designated for building, the profit depends on the quantity and quality of buildings that can be erected on it.

The pertinent decision variable of the developer in our case is the height of the building, on condition that the size of the lot permits a tall building (this point will be discussed later) and that the local authorities will approve the requested change of local regulations to a higher density. It will be shown later that the quality of dwelling in tall buildings is less affected by the density than in conventional buildings. For this reason the municipal authorities in many places are more inclined to permit a higher density with the increased height of buildings. Thus while the usual density for conventional buildings in Israel (3 to 5 floors) is around 100 dwellings per hectare, the density in tall buildings is 200–300 dwellings and more per hectare. This point will also be expanded later.

The land appreciates in value with the permitted increase in density. In a perfectly competitive market (free access to information on cost of resources, expected sale price, similar perception of the bidders, and so on), any extra value derived from the increase in the permitted density is transferred in its entirety to the owner of the land. The change in value can be inferred from the additional number of dwellings times the profit per dwelling. The profit is the difference between the price per dwelling and its costs of construction, both varying with the increase in the building density. It may be expected that the cost of development (both the direct cost of construction and the negative impact on the environment) will increase with density, and the value of land will therefore not rise proportionately with it. From a purely economic viewpoint, it is worthwhile to increase the density as long as the marginal revenue exceeds the marginal cost.

The theoretical behavior of land value under ideal conditions of a monocentric and homogeneous city is discussed in Mills and Hamilton (1994), Dipasquale and Wheaton (1997), and other sources. The ideal homogenous conditions rarely exist in practice, and the price of land is largely determined by the local conditions enumerated before. Their assessment for a given location with the use of hedonic models is discussed by Rose (1992), Rosen (1974), and others. The precise effect of a single parameter—in this case the permitted density—on the price of land is seldom available in the absence of sufficient and reliable data necessary for this purpose.

Moreover, the actual cost to the developer is usually determined in a two-stage process. The land is acquired by the owner at its original price based on the zoning density then prevailing. Later, after the increase in building density, the value of the land appreciates.

Due to the incompleteness of information on the marginal changes in costs and benefits at a particular location and the imperfection of the market, it is usually impossible to derive the precise density/value function of the land. It may be assumed, however, that within certain limits any percentage change in density will result in a proportional percentage change in the land value. The coefficient of proportionality will reflect the elasticity of the local land value with respect to building density.

The relationship mentioned above can be modeled with

$$P2 = P1 \cdot (D2/D1)^k \quad (1)$$

where $P1$ and $P2$ = value of land, respectively, before and after change in density; $D1$ and $D2$ = density in dwelling units per hectare before and after requested change; and k = coefficient of elasticity of land value with respect to change in density.

Eq. (1) implies a constant elasticity of value over the whole range of changes in density. This can be safely assessed if the spectrum of changes in density is not excessive. The value of k must be empirically deduced for each location.

Under various government systems the gain in value due to the change in the permitted density is taxed by the municipal authority. Another cost that must be accounted for is the interest on the initial investment in land during the process of change in the plan, which may sometimes be quite lengthy if the plan has a considerable environmental or social impact.

Consequently, the cost of land to the developer, C, can be assessed from

$$C = P1 \cdot (1+i)^T + (P2 - P1) \cdot k1 \quad (2)$$

where $D1$ and $D2$ = original and increased permitted building density on land lot, respectively; $P1$, and $P2$ = value of land before and after change in density, respectively; i = interest per pe-

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Table 2. Change in Land Value and Cost of Land per Dwelling Due to Increase in Building Density

Density prior to change (dwellings per hectare) ($D1$)	Density after change (dwellings per hectare) ($D2$)	Coefficient of elasticity (k)	Ratio of land value after and before change in density ($P2/P1$)	Ratio of land costs per dwelling after and before change in density (m)
100	200	1.0	2.00	0.84
100	250	1.0	2.50	0.78
100	300	1.0	3.00	0.74
100	200	0.9	1.87	0.80
100	250	0.9	2.28	0.73
100	300	0.9	2.68	0.68
100	200	0.8	1.74	0.77
100	250	0.8	2.08	0.69
100	300	0.8	2.41	0.64
100	200	0.7	1.62	0.74
100	250	0.7	1.90	0.65
100	300	0.7	2.16	0.59

riod, that is, cost of capital to developer; T = delay in approval due to change in plan; and $k1$ = tax rate on capital gains from density increase. The ratio, m, between the costs per dwelling before and after the change of plan can be deduced from

$$m=(C/D2)/(P1/D1) \tag{3}$$

Table 2 presents the change in the value of a land lot and the change in the cost of the land per dwelling for different densities and different values of the elasticity coefficient, k. The table shows that the increase in the permitted dwelling density from 100 to 200–300 dwellings per hectare reduces the cost of land per dwelling by 15–40%, depending on the elasticity coefficient in the particular location under consideration.

Developer's View—Cost of Financing

In its initial stages, a typical construction project is characterized by a negative cash flow (excess of costs over revenues). The cash outlays are balanced by income only in very advanced stages of the project.

The cost of financing may be calculated (Warszawski 2003) as the difference between the net present value of the developer's cash flow, given his or her actual cost of capital (used as a discounting interest rate), and the present value when the cost of capital is 0.

The cost of financing can accordingly be calculated from

$$f=(1/\Sigma_t C_t)\cdot\{\Sigma_t R_t-\Sigma_t C_t-[\Sigma_t(R_t-C_t)/(1+i)^t]\}\ \ldots \quad (t=0,1,\ldots,T) \tag{4}$$

where f = rate of financing cost (as percentage of project cost); C_t, R_t = cost and revenue, respectively, in period t ($t=0,1,\ldots,T$); and i = real discounting rate (cost of capital) to developer.

In order to evaluate the impact of the height of the building on the financing cost in typical building projects, the following simplifying assumptions have been made:

1. Purchase of land is made at the inception of the project, and the construction begins T_o months afterward;
2. Construction costs are evenly divided over the construction period T;
3. Sales are to commence T_d months after the construction start
4. Cash receipts from sales are evenly divided over the period of sales T_s.

Consequently, the monthly sales can be calculated with

$$Q=(1+p)\cdot C/T \tag{5}$$

and the cost of financing

$$f=p-\{Q\cdot[(1+i)^{T_s}-1]/i\cdot(1+i)^{T_s}/(1+i)^{T_o+T_d}-C_L\cdot C - [(1-c_L)C/T]\cdot[(1+i)^T-1]/i\cdot[(1+i)^T/(1+i)^{T_o}]/C \tag{6}$$

where Q = monthly receipts from sale; C = total cost of the project; p = profit margin or profit/cost ratio; c_L = cost of land as fraction of total project cost; T = duration of construction (in months); T_o = delay of construction start after the purchase of land (in months); T_d = delay in the start of sales after the start of construction (in months); and T_s = duration of sales (in months). The other parameters are defined as for Eq. (4).

Note from Eq. (6) that the main parameters that significantly affect the financing cost of a construction project are the duration of construction, timing of the buyer's payments, cost of land (expressed as its share of the total cost), and developer's intended profit. The duration of construction depends on the size of the project, that is, the number of dwelling units in it.

All other parameters remaining constant, the impact of the building height can be assessed by using Eq. (6), to compare, the financing costs of two model buildings: one conventional (3–5 stories high), the other tall (30 stories high). The construction of the conventional building may take, depending on its particular circumstances, between 8 and 12 months; that of the tall building, between 22 and 26 months.

The financing cost of the two buildings is given in Table 3, assuming

- Cost of capital $i=8\%$ per year;
- Cost of land—$CL=0-50\%$ of C;
- Profit $p=0.2C-0.3C$
- Construction delay T_o = 2 months
- Sales duration T_s = 4 months
- Sales start—$T-T_d$ = 2 months

Note from Table 3 that in this example the difference in financing cost between the tall and the conventional building amounts to 5–7% of the total project cost. The financing costs increase with the desired profit rate and with the share of the cost of land in the total project cost.

Table 3. Financing Costs of Buildings with Different Construction Times

Construction duration (months)	Financing cost as percentage of total project cost			
	$C_L=0,\ p=0.2$	$C_L=0.3,\ p=0.2$	$C_L=0.5,\ p=0.2$	$C_L=0.3,\ p=0.3$
Conventional building				
8	3.7	5.0	5.8	5.6
9	4.1	5.5	6.3	6.2
10	4.6	6.0	6.9	6.7
11	5.0	6.5	7.5	7.3
12	5.4	7.0	8.0	7.8
Tall building				
22	9.2	11.7	13.3	13.1
23	9.6	12.1	13.8	13.5
24	10.0	12.6	14.3	14.2
25	10.3	13.0	14.9	14
26	10.7	13.5	15.4	15.2

Developer's View—Cost of Risk

The risk from the developer's point of view is defined in this study as the probability that his or her project will fail to attain his or her minimum criteria. In our case, as stated earlier, these criteria require a positive net present value.

The risk so defined may result from three main types of factors:

1. Construction costs exceed their expected amount in one or more construction periods;
2. Sales proceeds fall below expected value in one sale period or more; and
3. Duration of construction exceeds its expected time,

Given the possible range of divergences of each of these factors from their expected values, the risk involved in a particular project can be evaluated with methods presented in Chapman and Ward (1997), Flanagan (1993), and other sources. Should the risk be considered excessive, the developer may invest additional resources in reducing the variability of the project's key factors, thus bringing the project to the acceptable risk level. The cost of the resources expended for this purpose may be viewed by the developer as the cost of risk in the project.

In many cases, the adverse effects of uncontrollable deviations in the early stages of the project can be mitigated by timely intervention. A flexible building setup can allow for changes in design, organization, construction pace, and so on, which can largely reduce the adverse effects of risk factors. As a rule, the taller the building, the greater the number of constraints the developer has to overcome in any change of design, technology, or contractual obligations toward clients once construction has begun. The resources necessary for bringing a tall building to an acceptable risk level will therefore be larger than those needed for a conventional building.

Given the riskier nature of tall building projects, it is also possible to account for the difference in risks by increasing the risk component in the developer's desired rate of return.

The extra cost of risk in a construction project can then be calculated from

$$s=1/C\cdot\Sigma_t\{(R_t-C_t)\cdot[1/(1+i)^t-1/(1+i+\Delta i)^t]\} \qquad (7)$$

where s = cost of risk as fraction of total project cost; and Δi = risk compensation component.

With the aid of Eq. (7) it is possible to find out that an increase of 2% in the required rate of return due to a higher risk will increase the cost of financing by 0.3% of the total project cost.

Developer's View—Benefit of Scenery

One of the main benefits of a tall building as perceived by the dweller is the view available on the upper floors of the building, even in localities without particular scenic features such as proximity to the sea, a river, a forest, and so on. The value of this benefit can be assessed by the extra price that the dweller is willing to pay for a dwelling on the upper floors of a building. The survey conducted by this writer in Israel revealed that the price of a dwelling in a tall building escalates at 1–2% of its basic cost per each additional floor, starting at the elevation of the top floor in the surrounding conventional buildings. At this elevation, the prices of equivalent dwellings in the tall and conventional buildings are roughly the same.

If we assume that the tall building is surrounded by conventional buildings 6 stories high, then the prices of dwellings in the tall building will start to escalate at the 7th floor. Consequently, the average price per dwelling for a 1–2% price escalation per floor will be in a 10 story building 1–2% higher than in a neighboring conventional 6 story building, 5.5–11.5% in a 20 story building, 10–20% in a 30 story building, and 15–30% in a 40 story building.

This intangible benefit for the dweller turns therefore into a commercial benefit for the developer.

Summing up the developer's viewpoint, the tall building alternative will be preferable to the conventional one if the savings in the cost of land and the extra income that can be obtained for the higher floors will exceed the higher constructon costs, the financing costs, and the cost of higher business risk for the developer.

Dweller's View—Principles

The dweller buys or rents the building from the developer for an extended period of time. The objective of the dweller is to maximize his or her welfare associated with his or her dwelling there. The economic aspects of that welfare will be defined in this context as the benefits derived from dwelling less the costs incurred for this purpose.

In the context of this study, the benefits derived by the dweller from his or her dwelling can be divided into (1) the basic services expected from any dwelling regardless of the building's height, and (2) the benefits specific to a tall building and therefore of main interest in this study. These latter benefits include a more

Table 4. Free-Space Index—Whole-Space Approach

	Net density											
	100 dwellings/ha			200 dwellings/ha			250 dwellings/ha			300 dwellings/ha		
Building height (floors)	Minimal lot area (m^2)	Percent of free space (%)	Free-space index	Minimal lot area (m^2)	Percent of free space (%)	Free-space index	Minimal lot area (m^2)	Percent of free space (%)	Free-space index	Minimal lot area (m^2)	Percent of free space (%)	Free-space index
4	1,600	63	100	800	25	40	—	—	—	—	—	—
10	4,000	85	137	2,000	70	112	1,600	63	100	1,333	55	89
20	8,000	93	145	4,000	85	137	3,200	81	131	2,666	77	124
30	12,000	95	153	6,000	90	145	4,800	88	142	4,000	85	137
40	16,000	97	155	8,000	93	147	6,400	91	147	5,300	89	143

attractive view from the upper floors, more open space near the building, and the availability of special amenities not usually available in a conventional building.

The major cost parameters from the dweller's viewpoint are the costs associated with the management of the building and other costs, most of them intangibles, that reflect any inconvenience (or discomfort) liable to be caused by the height of the building. These inconveniences are reviewed in Conway (1977) and other sources. The costs found pertinent to this study are explored later.

Dweller's View—Benefits of Tall Building

As mentioned before, the special benefits of a tall building consist of the better view one can enjoy on the upper floors of such a building, more open spaces, and the ability to use common services that are usually unavailable in smaller buildings.

Benefit of Scenery

The upper floors of a tall building offer an unobstructed view and more attractive scenery than on any floor of a conventional building. The dweller's preference for the view from upper floors is reflected in the prices of dwellings examined in the context of this study (see the section on the benefit of scenery). The economic aspect of this benefit is therefore transferred to a large extent from the dweller to the developer. One can observe, however, that the dweller values the benefit of the scenery at least at the extra price he or she is willing to pay the developer. Any sum he or she was willing to pay above the requested price and did not have to may be considered his or her net surplus.

Benefit of Open Space

An open space near the building can be used for gardening and other types of recreation. Buildings that have more free space than others can be considered as offering an additional benefit to the dweller. The measurement of the open space for this purpose can follow one of these two approaches:

1. The open space is a common good, and each dweller derives his or her pleasure from the whole open space near the building. The measurement of the open space as a percentage of the total area of the lot, and the pertinent benefit index based on this principle are shown in Table 4.
2. The benefit of an open space depends on the dweller's share of it. In that case, the benefit index is derived from the total amount of open space on the lot divided by the number of dwellers, as shown in Table 5.

The indices in Tables 4 and 5 are compiled for different densities and heights of the model building (as described in the section on methodology). The minimal lot size in Tables 4 and 5 for each combination of height and density has been derived while considering the number of dwellings in the building (four per floor) times the number of floors and the permitted number of dwellings per hectare. The benefit of the dweller in a 4 story building and a building density of 100 dwellings per hectare serves as the basis for both types of indices. Both approaches show the benefit of open space as measured by the index to be higher for tall buildings than for conventional ones. The benefit of the tall building is particularly evident with the first approach: the increase of the net density by 100–200% with respect to the conventional building scarcely affects the free-space index, which remains significantly higher (by 50–250%).

Table 5. Free-Space Index—Space-per-Dweller Approach

	Net density											
	100 dwellings/ha			200 Dwellings/ha			250 dwellings/ha			300 dwellings/ha		
Building height (floors)	Minimal lot area (m^2)	Free space (m^3)	Free-space index	Minimal lot area (m^2)	Free space (m^2)	Free-space index	Minimal lot area (m^2)	Free space (m^2)	Free-space index	Minimal lot area (m^2)	Free space (m^2)	Free-space index
4	1,600	62	100	800	12	19	—	—	—	—	—	—
10	4,000	85	137	2,000	35	56	1,600	25	40	1,333	18	29
20	8,000	90	145	4,000	42	67	3,200	32	52	2,666	26	42
30	12,000	95	153	6,000	45	72	4,800	35	56	4,000	28	45
40	16,000	96	155	8,000	46	74	6,400	36	58	5,300	30	48

Table 6. Management Costs of Residential Building for Various Building Heights

	Costs in dollars/m^2/month and in percentage of conventional cost per sqm per month							
	3–5 stories[b]		10–20 stories		21–30 stories		31–40 stories	
Management activities	$/sqm	%	$/sqm	%	$/sqm	%	$/sqm	%
Administration	0	—	0.27	—	0.19	—	0.16	—
Operation	0.20	100	0.20	100	0.17	85	0.16	80
Cleaning and gardening	0.08	100	0.08	100	0.08	100	0.08	100
Maintenance	0.17	100	0.27	159	0.44	259	0.59	347
Other[a]	0	—	0.12	—	0.08	—	0.06	—
Total	0.45	100	0.94	209	0.96	213	1.06	236
Total + overhead (12%)	0.45	100	1.05	233	1.07	238	1.18	262
Optional (per sqm)[c]								
Guards and surveillance	2.34	100	0.52	22	0.31	13	0.22	9
Swimming pool and gymnasium	2.80	100	0.78	28	0.54	19	0.39	14
Total + optional	5.59	100	2.35	42	1.92	34	1.79	32

[a] Including insurance, and legal and financial consultation.

[b] Administration by a voluntary committee.

[c] Unavailable in conventional buildings. Cited to demonstrate the potential economy of scale in tall buildings.

The benefit is less conspicuous with the second approach but is still very significant when comparing tall and conventional buildings at the same lot density.

Benefit of Additional Services

Another advantage of tall buildings is the possibility of offering its dwellers certain services at a much lower cost than a conventional building can because the cost of these services is shared by a larger number of users. Typical services offered are watchmen and surveillance at the entrance and recreational facilities, such as a swimming pool and gymnasium. The benefits associated with these services may be assessed from their cost in a tall building versus their cost in a conventional building, if offered there. It can be seen from Table 6 that the cost of these services should be provided also in a conventional building but would be higher by 400–500% than in a tall building.

Evaluation of Intangible Benefits

The general principles of the evaluation of intangibles through the willingness to pay have been explained in the section on methodology. Their quantitative evaluation in monetary terms can be achieved through weight assignment versus other monetary costs or benefits. The elicitation methods applied for this purpose are found in Saaty (1980) and other sources, and will be explored in more detail in the context of the city view in the sequel paper.

Dweller's View—Costs Involved in Use of Tall Building

The main limitations of the tall building as identified in this study include the relatively high costs in its use and also some intangible disadvantages.

Costs of Building Management

The costs in the use of particular interest in a tall building are the expenses that the dweller has to bear to assure the satisfactory functioning of the common systems and facilities of the building.

These costs include

1. Operation of common services and systems: elevators, water storage tanks, pumps, emergency electrical systems, and so on;
2. Maintenance of these systems: preventive maintenance, necessary repairs, and periodic replacement of wornout items;
3. Cleaning of common property: stairs, landings, lobby, and building exterior;
4. Administration of various tasks associated with these services: billing residents, ordering services, control, inspection, accounting, and so on;
5. Insurance and city tax on common property areas; and
6. Overhead and profit of management company.
   Optional services in tall buildings may also be offered. These include
7. Guards at entrance and surveillance of stairs and elevators; and
8. Operation of common recreational facilities, such as swimming pool, gymnasium, and so on.

Basically there are two options for building administration. In one arrangement, all the managerial activities are performed on a voluntary basis by elected representatives of the residents. This arrangement is common in Israel for conventional cooperative housing. Experience shows, however, that if the number of dwellings exceeds 50–60, such a voluntary arrangement may not suffice. In the other arrangement, a professional management company is employed and performs all the administrative tasks necessary for the provision of maintenance and operational services. This arrangement proves to be much more expensive because the many tasks that would have been done voluntarily must be paid for, together with the overhead expenses, profit, and a value added tax that is payable on any services procured from outside.

The consequent costs in use are shown in Table 6. They were compiled on the basis of the information obtained from several major facility management companies with regard to their tasks in a tall building and a subsequent itemized estimate of expenses involved in each task

It can be seen in Table 6 that the essential building management costs per period in tall buildings are higher by approximately 100–200% than in buildings of conventional height. Tall buildings, on the other hand, can offer residents optional services such as a swimming pool, guards, etc. at a reasonable rate.

Intangible Costs

Many types of intangible costs were enumerated and examined in Conway (1977) and other sources. Two types of intangible costs were of economic significance and found pertinent to this study:

1. Relative difficulty of escaping from upper floors of building in case of fire and other dangers; and
2. Dependence on elevators—waste of time in waiting and disruption in case of their breakdown.

The general approach to these problems has been discussed in the context of dealing with risks. The safety risks should be defined, evaluated, and brought to an acceptable level (or to the level prevalent in a conventional building) by the use of better equipment and more reliable control procedures. The cost of these provisions can be considered as the economic value of this parameter.

A similar approach can be adopted with regard to the elevators. The risk of their breakdown or delay can be measured and brought to a desired level. The value of extra time associated with waiting and traveling can be assessed by using the appropriate value of time (the economic value of traveling time is a standard parameter in the economic evaluation of public transportation projects).

Summing up the dweller's viewpoint, for a tall building to be desirable, its differential economic benefits—scenery, free area around, and available services—must exceed the costs involved with its management, the difficulty of escape, and the inconvenience of depending on the elevators' service.

Discussion and Conclusions

The object of this paper was to present and examine a method for the economic analysis of the desirability of tall residential buildings from the points of view of the developer and the dweller. The viewpoint of each party was reflected in its objective; the discussion focused on those of the project's parameters that had an economic impact on that objective. The parameters were considered to be benefits if they had a positive impact on the objective of the party, and to be costs if the impact was negative.

The following discussion will first briefly summarize the methodology of the study and its findings. It will then also examine their applicability under other than Israeli conditions.

In the examination of the various cost versus benefit factors, the adopted methodology used a model representing a typical residential building with its height as the major independent variable. That approach seemed, and still seems, preferable to the statistical analysis of a sample of data from actual projects, for both practical and methodological reasons, whenever the engineering and economic aspects of the problem to be examined could be represented by such a model and the model permitted the performance of a sensitivity analysis of its most important features. The simplification introduced, of focusing only on cost and benefit differentials, did not seem to impair the generality of this approach.

The study indicated that the cost of land per dwelling declines with the increase in building density usually permitted in tall building projects. The cost of land has been calculated in the context of the two-stage land appraisal process prevalent in Israel and in many other countries. For a more general view of the problem, one also has to consider the case when the existing zoning regulations permit the requested building density a priori. In that case the additional land value will be reflected in the developer's cost. When compared with its cost at conventional density, the additional cost of land will depend on the increase in the number of dwellings per lot and the decline in the profit per dwelling inherent in such increase.

Theoretically, therefore, the change in the cost of land will not affect the cost per dwelling to the developer. In reality, however, one has to consider the imperfections of the market, which can benefit the developer. These imperfections may conceivably enable the developer to reduce the extra cost or increase the price per dwelling more than under perfect competition. In that case one can safely assume that some reduction in cost will be attained with the increased density, This is also borne out by the evident effort of almost any developer to raise the permitted density as much as possible in areas of high demand.

The cost saving will occur in any case if the increase in density is granted to the developer after his or her acquisition of the land and if the tax on the added value does not amount to the total gain. However, the marginal profit can seldom be assessed directly, considering the intangibles involved and the imperfections of the market.

The approximate method suggested in the study, which assumes an elasticity of change, *k*, adaptable to the particular local conditions, seems reasonable and is convenient to use.

It can be concluded that in city centers where the value of land constitutes a large share of the project's cost, gains can be expected due to a higher building density and can be roughly assessed with the approach presented here. In fact, the saving in the cost of land and its total effect on the profit to be realized from the particular lot seem to be the main driving force for tall building development.

The other major factor—the cost of construction—has been shown to increase considerably with the building's height, especially in the range of 20–40 floors.

With regard to the results obtained, the following observations are made:

1. The major component of the additional construction cost (30 to 40% of the total) was found to be the underground parking. This component depends very much on the prevalent parking regulations. The requirement of 1.5 parking spaces per apartment may be considered rather low in high-income neighborhoods, but excessive in neighborhoods served by efficient public transport. The requirement of fully underground parking may also seem too stringent for some municipal areas.
2. The model building assumed four dwellings per floor and roughly 530 m^2 per residential floor. Since the cost of systems increases faster when adding floors than when increasing floor area, it is expected that for larger floors the additional cost due to an increased number of floors will be smaller than in this study.
3. For lack of data, the study did not examine either the influence of scale in procurement or that of the learning effect in labor. These economically advantageous effects were therefore omitted, as were the additional costs of equipment and organization in tall construction. All these effects may have a considerable influence and should be studied in more detail.

As examined here, the cost of financing was assumed to incorporate an interdependence between the height of the building, that is, the number of dwellings per building, and the construction time. If for some reason a commercial or engineering constraint prevents the use of individual conventional buildings before the whole project (with the same number of dwellings as in the tall building) is completed, the financing costs of both projects will be the same. On the other hand, if the sale can be concluded only at

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the completion of the project and not during construction—as assumed here—the difference in the financing cost will be bigger.

The risk inherent in tall buildings was traced mainly to their inflexibility, that is, their inability to cope with changes, whether constrained by the market or requested by a customer. Of the three main sources of risk—construction costs, sales, and their timing—the last two, which are obviously interdependent, are more risk prone. If these risks can be eliminated by a prior sale agreement, the additional risk in tall buildings will be insignificant.

It can be concluded, with regard to the developer, that the overall construction expenses in tall buildings will be higher, sometimes significantly so, than in conventional construction. The purely economic feasibility of a tall building therefore depends on the savings in the cost of land. The higher the value of land, the greater will be the propensity of developers to engage in constructing tall buildings.

The main factors that should determine the attractiveness of tall buildings from the dweller's viewpoint are the significantly larger costs in their use, which must be counterbalanced by extra benefits.

The difference in these costs results mostly from the additional service systems and in some part from the self-management of dwellers in conventional cooperative housing. In cases where, for some reason, conventional housing is managed by an outside company, or conversely when a tall building is self-managed (in which case there is obviously a higher risk of deterioration), the extra costs in the use of a tall building will be significantly lower.

The increased cost of management of common property must be balanced by such intangible benefits as view, open space, and additional amenities. It is the tentative conclusion of this study that the benefit of a tall building will be valued higher by prospective buyers of a higher socioeconomic class, who will be less affected by the higher cost of its use and willing to pay more for the amenities of safety and recreation and the benefits of space and scenery. On the other hand, the success of tall buildings in some places as housing for low-income tenants (for example, in Hong Kong) requires more study, especially the influence of local standards and conditions. In all cases the potential of intangible benefits can be more readily realized in locations with beautiful scenery, which is largely obscured in buildings of conventional height.

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