CENTRAL BUREAU OF STATISTICS

MINISTRY OF CONSTRUCTION AND HOUSING

SURVEY OF RESIDENTIAL BUILDING TECHNOLOGIES IN ISRAEL

BUILDINGS UNDER ACTIVE CONSTRUCTION AT THE END OF 2002

Jerusalem, August 2004

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PREFACE

The current publication presents data from the Survey of Residential Building Technologies in Israel which was conducted regarding buildings under construction at the end of 2002.

The Survey of Residential Building Technologies is the first one to be initiated and funded by the Ministry of Construction and Housing, and conducted in collaboration with the Central Bureau of Statistics.

The publication aims to respond to the need of state institutions, research institutions, government ministries (particularly the Ministry of Construction and Housing), and other institutions for detailed data on methods and technologies of residential building in Israel. The type of data published here are necessary for planning, administration, and research related to various technological and economic issues that concern the construction industry, including industrialization of construction.

The publication presents detailed data on residential building technologies, including mechanization that exists on the site, and methods used to construct components of buildings, which include: construction of columns, ceilings, external walls, internal partition walls, plumbing; external cladding, internal cladding, floor tiling, and supply of windows and doors.

The survey data will be used subsequently by the Ministry of Construction and Housing to develop an Industrialized Construction Index for residential building in Israel. In order to enable a comparative analysis of changes over time, we expect to repeat the survey at intervals that will be determined later.

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Jerusalem, 2004

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INTRODUCTION

1. General Background

The building industry, in contrast to other industries, is known for its conservative attitude towards adopting advanced technologies. To this conservatism has been added, in the last thirty years, the availability of cheap labour. As a result the industry initially developed a dependence on Palestinian workers, and subsequently on foreign ones. Furthermore, the industry has failed to recruit sufficient Israeli building workers, especially in "wet" trades such as plastering, tiling, formwork, stone cladding, etc. The capital inventory for a worker in the industry is very low and is about half the average value in OECD countries.[1] The overall productivity of the industry is also very low, and has decreased by 47% in the period from 1995 to 2002.

A survey of building technologies used in residential building in Israel was initiated and funded by the Ministry of Construction and Housing. S. Engel Engineers Ltd. and I.K. Economic Plannig Ltd. prepared the questionnaire and estimated the labour input and the weighting of the components of building, and the Central Bureau of Statistics carried out the field survey.

The aim of the survey was to acquire, process, and analyze the existing infrastructure related to residential building technologies in use in Israel at a given point in time. An evaluation was made of the validity of the assumption widely held among the builders and others in the industry that in residential building, which is the largest sector of the Israeli building industry, extensive use is made of labour-intensive conventional building technologies, and only limited use is made of industrialized methods, which require large investments of capital, knowledge, and materials.

The survey also addressed the issue of whether a statistical relationship exists between residential building technologies and the various characteristics of the building, the project to which it is related, and the builder.

The data collected in the survey will be used by the Ministry of Construction and Housing, which is developing the Industrialized Construction Index. This index will permit measurement of the extent and depth of industrialized methods in residential building, with various technologies and elements, will present a picture of the existing situation, and will permit comparison of the changes over time.

2. Definitions

Building begun – beginning the digging of the foundations.

Building completed – when the building is technically finished and is ready to function or when use is being made of more than half its area.

Under active construction – buildings in the process of active building, but as yet incomplete; excluding buildings whose construction was halted a long time ago (these are “buildings not under active building”).

Building area – this includes external walls, balconies, and the area constructed under columns.

Dwelling unit – a room or set of rooms in a permanent or temporary structure, intended for residential purposes. It includes service rooms, and has a separate access from the street or from an area common to other dwelling units inside the building.

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[1] Bank of Israel, research department, Report for 2002, Jerusalem, 2003.

Initiator – the entity or person who plans the construction (determining location, standards and area) and inspects it.

Public building – building initiated by the government, national institutions, local authorities, and companies entirely controlled by these institutions.

Private building – all buildings except public buildings.

Firm size – size groups determined by the register of contractors at the Ministry of Construction and Housing were consolidated into three levels according to the following criteria: *"small" firm* (maximum 2,500 m^2 of construction per year), *"medium-size" firm* (up to 10,000 m^2 of construction per year) and *"large" firm* (unlimited construction area).

A new residential building – a building in which the area designated for residential purposes forms at least 50% of the total area of the building and which is being constructed on a lot in which a building does not exist, or on foundations of a demolished building of which there remain no walls which can be used in the new building.

Number of storeys – the number of storeys in a new building also includes the ground storey, but does not include the open storey under the pillars (without walls).

Residential building – a building designated for tenancy by single people and families to live there.

Industrialized building – refers to a broad range of methods, technologies, and means, which involve intensive use of equipment and knowledge, and which reduce the labour input required for building, and the time of execution, and improve the quality of the product.[1] For example, when used in the finishing stages of building, they reduce the amount of "wet" work and obligate the use of large, ready made elements, which are joined together on site.

Prefabricated building – an outstanding example of industrialized building is prefabricated building. In this form of building large structural elements are used, which are made in a factory, and subsequently assembled on the building site. In the case of prefabricated reinforced concrete elements, the formwork, reinforcement, and casting are performed in an external factory instead of on the building site. Maximum utilization of factory production is achieved when the prefabricated frame and exterior shell elements also incorporate a large part of the building finish work – cladding, insulation, windows, plumbing, etc.[1]

Conventional building – in contrast to industrialized building technologies, traditional conventional building is labour-intensive. It is mainly used for residential buildings, and employs a frame of reinforced concrete columns and ceilings, external and partition walls made of concrete blocks or other blocks, plastered external and internal walls, and terrazzo or ceramic floor tiling on a sand and mortar base.[2]

Tower crane – a means for lifting raw materials and other products, comprising a tower and a horizontal arm. The tower crane is capable of rotating 360º about its axis. It may also move forward and backward a few meters on rails, but it is not mobile on the site except by using its long arm which covers the area of the site.

Self propelled crane – a lifting and handling device capable of moving on the site on wheels or tracks.

Telescopic fork-lift (such as that of Manitowok) – a self propelled raising device having an adjustable arm (up, down, and sideways), which can be extended and retracted (telescopically) as required.

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1 Engel S. and research team, *An economic-pricing model of economic feasibility of transition to industrialized residential construction*, Jerusalem, 2001 (Hebrew only).

2 Warshawsky, A., Becker, R., Rosenfeld, I., *Industrialization of Construction – obstacles and their solution*, The National Institute for Building Research, Haifa, 1999, p.1 (Hebrew only).

External elevator (such as that of Alimak) – an elevator for passengers and tools intended to be installed externally on buildings during construction.

Fork-lift – a device for raising and handling pallets and loads, mainly from vehicles and ramps. It has limited mobility, weight capability, and height capability.

Industrialized steel forms (tunnels) – forms made of steel or steel and plywood, which come as large surfaces or as modular elements, and which create the moulds for casting. They can be assembled in various geometric shapes to meet the design and execution needs, either as a wall or a tunnel (a tunnel is in fact a room or space with two walls and a ceiling), for example products manufactured by S.A.B. Metal Works Ltd. & Barak Metals Ashqelon Ltd.

Other industrialized forms – as above, but made by PERI, DOKA, etc.

Solid ceilings – reinforced concrete ceilings having no filling or spaces, cast on site.

Solid slab ceilings (bridging above rooms and areas) – reinforced concrete slabs cast in the factory and brought as flat units of large size. They are intended to span large areas, and an additional thin layer of concrete is cast on top of them.

Ribbed ceiling – the ceiling comprises concrete ribs and filling material which together produce an inverted T section.

Dual skin (Isocal) ceiling – a ribbed ceiling with an additional lower skin, producing a section closed on all sides.

Post or pre-stressed solid slab ceilings – concrete ceilings in which cables are inserted before casting the concrete, and are tensioned before or after casting. The cables form part of the reinforcement of the ceiling.

Industrialized ceilings incorporating tunnels – a method of casting using forms which produce the geometric shape of a tunnel, for walls and ceilings (steel forms in the shape of a tunnel).

Gypsum supplied in bulk – ready mixed gypsum supplied in storage containers similar to huge drums.

Partition walls made of gypsum board/cement board – use of building boards such as gypsum board or cement board (a mixture of cement and wood shavings), for construction of partition walls and for covering walls instead of gypsum, based on sheet steel profiles which form a structural frame from the floor to ceiling, to which the boards are attached with screws. In damp areas such as toilets, bathrooms, kitchens, balconies, etc., (green) water-resistant gypsum board may be used.

Partition walls made of gypsum blocks – use of gypsum blocks.

Floor tiling by gluing to self leveling screed – use of a layer of self leveling screed to which the floor tiles are glued using a thin layer of adhesive.

Galvanized steel piping – pipes which underwent a process during manufacture to prevent rust and consequent leaks, for a long period of time.

Modular industrialized piping (Pexgol, SP, and others) – plastic or PVC and/or aluminum piping used for plumbing.

3. The Methods of the Survey

3.1 The survey population and the sampling framework

The survey population included all the residential buildings, in all types of localities, with private or public initiative, which at the time of the survey were at least 4 months after commencement of building and whose building had not yet been completed. Privately owned new housing construction was not included in the survey.

The sampling framework of the survey of building technologies used in residential building in Israel (a file from which the sample for the survey was extracted) was derived from the database of the Central Bureau of Statistics which contains all the buildings whose construction has been started and in accordance with the definition of the population of the survey. *The framework included buildings intended for residential purposes and mixed buildings (buildings intended partially for residential purposes and partially for other purposes, such as business), whose construction had never been halted or canceled, and whose construction commenced between the dates 1.1.1998 and 1.11.2002.* Buildings whose construction commenced before 1.1.1998 were removed from the framework, because they were exposed to lack of reporting in the database regarding completion or halting of construction. The framework did not include structures described in the database as additions to buildings, but only new buildings.

The framework for sampling included a total of 3,718 buildings.

3.2 The sampling method

The sample of buildings for the survey is a single stage layers sample, where each layer of sampling is a storey. All the buildings were classified into layers in accordance with the number of storeys known in the framework file, and the sample of the buildings was allocated between the layers while reinforcing the layers of high rise buildings at the expense of the other layers.

Buildings with 10 or more storeys were definitely sampled. In other words, a full survey was made for such buildings of the characteristics investigated in the survey. In all other storeys (layers) the records were sorted by geographic characteristics for each storey separately, and a random-systematic sample was obtained for the buildings with a uniform probability for the layer (but differing between layers).

A total of 508 buildings were sampled for the survey.

3.3 Method of data collection

After identification of the contractor actually constructing the building sampled, the suitable person to complete the questionnaire was located by phone enquiries, having general knowledge of construction and very familiar with the building being sampled and the methods and equipment used in its construction. This was generally the site engineer or the project manager. The survey questionnaire was sent to that person by the computer using the WinFax software. After completion of the questionnaire it was returned to the Central Bureau of Statistics and its data underwent a structured process of inspection and recording.

The survey questionnaire (see Appendix 1) was intended to be completed by the person making the report, and included a range of questions regarding four major topics:

a) The location and identification details of the building

b) Details of the builders

c) Details of the building, the project, and the site

d) Mechanization in the building site and methods of implementing the major structural elements: method of constructing the columns, ceilings, external walls, partition internal walls, plumbing systems; methods of external cladding, internal cladding, floor tiling; and method of supplying windows and doors

3.4 Results of the sample data collection

Out of the 508 buildings sampled, for 473 a questionnaire was received, and they were included in the survey processing. Regarding the other 35 buildings for which a questionnaire was not received, it transpired that 16 of them do not belong to the survey population (mainly because their construction was halted/ frozen), 8 did not reply (mainly because of a refusal to participate in the survey), and in 11 cases it was not clear if they belong to the survey population (problems in locating and identifying the buildings sampled).

3.5 Method of estimation

Every building for which a questionnaire was completed was given an expansion coefficient which expressed the number of buildings it represents. This coefficient was calculated while taking into account the design of the sample (the sampling probabilities for the number of storeys) and the levels of response on each storey.

The estimates are presented in this publication in frequency tables of construction technologies, by characteristics of the building, the site, and the builder. The main method of construction is presented at the head of the tables (the column heading), and includes that method as well as all of the combinations of the method that were used on the site (see Appendix 2), and methods of construction that require a greater input of work hours (see Appendix 3). The combinations of methods belonging to the same group are listed in footnotes to each table in the publication.

4. Main Findings

Equipment on the building site

Tower crane – was found to be in use in 47% of the total area of residential building, generally by medium and large contractors (see Table 1).

External elevator – is regarded as the most effective mechanical device regarding labour input on the building site. An external elevator was found to be in use in 18% of the total area of residential building. An external elevator is commonly used in buildings having 11 or more storeys and 50 or more dwelling units, constructed privately as part of large projects (in which there are more than 200 dwelling units), and is mainly found in the Tel Aviv and Central districts.

Telescopic fork-lift – is used on sites forming about 18% of the area of residential building. This equipment is more frequently used in construction of buildings of up to 5 storeys and up to 24 dwelling units, in public building, on building sites having a sloping area (an incline of 7% to 12%).

Working methods

Columns and ceilings - 84% of the area of residential building was built using columns cast on site (see Table 3). 38% of the area is constructed using steel forms. Cast columns in steel forms are common in buildings having 16 or more storeys and 25 or more dwelling units, constructed privately by large contractors, in projects comprising more than 300 dwelling units. 29% of the area is constructed using wooden/plywood forms. The estimates regarding wooden forms are more common in buildings of up to 5 storeys with less than 24 dwelling units, built by public initiators, in projects in which not more than 99 dwelling units are constructed, mainly in the Haifa and Northern districts. About two thirds (69%) of the residential building area is constructed using wood/plywood forms, and even solid concrete ceilings are cast on site using wood/plywood forms (see Table 7).

In about 14% of the area of residential building, load bearing walls are used, without the need for columns, so that there is no need for labour input to erect columns on the building site. This method is more common in public buildings, in projects in which between 300 and 400 dwelling units are being built.

In about half (46%) of the area of residential building, use is made of solid concrete ceilings cast on site with wood/plywood forms. This method of construction requires high labour input per building unit and is very common in buildings having up to 5 storeys, constructed in the public sector, in projects in which up to 200 dwelling units are being built (see Table 5).

Three other major methods for construction of ceilings are employed to a similar extent (each of them represents 16%-17% of the area of residential building). They are: a) Solid ceilings cast on site; b) Solid ceilings cast on site using metal forms and additional methods; c) Ribbed ceilings cast on site.

External walls: construction and cladding – about a third (35%) of the external walls are constructed using Itong blocks (see Table 9). These are most common in relatively small projects (up to 99 dwelling units) and in relatively low buildings (up to 10 storeys). Methods with low labour input requirements, such as concrete walls cast on site with external and internal finish, or prefabricated walls, were used in only one fifth (20%) of the area of residential building.

In more than half (55%) of the residential building area, the walls are clad by gluing stone/ceramic tiles/mosaic (more than half [73%] of the walls are built of Itong blocks – see Table 13). This method is more widespread in the Haifa and Northern districts than in the Tel Aviv and Central districts. In about a quarter (27%) of the walls the cladding is done during production of the wall (see Table 11).

Internal partitions: construction and cladding – in more than half of the area of residential building (53%) the internal partitions are constructed of concrete blocks. This building technology is preferred in public building and in relatively small projects (up to 99 dwelling units, see Table 15). In more than half (56%) of this building area the internal walls are covered with factory-made plaster applied on site (see Table 19).

On about 19% of the area of residential building the internal partition walls are made of Itong blocks. In about 14% of the area of residential building the internal partition walls are made of plaster blocks.

The internal walls are clad using three main methods: a) factory-made plaster applied on site (45% of the total area of residential building); b) Plaster prepared on the site (32%); and c) Gluing plasterboard (23%) (see Table 17).

Floor tiling – in the vast majority of the area of residential building (96%) the floors are tiled on sand filling, while in the rest of the area (4%) the tiles are glued to self leveling screed (see Table 21).

Plumbing – in most of the area of residential building (96%) the plumbing consists of industrialized plastic/aluminum piping, etc. (see Table 23).

Windows and doors – standard doors (off-the-shelf products) are used in 80% of the area of residential building (see Table 27). In contrast, standard windows are used in only 14% of the area of residential building (see Table 25). In those buildings in which use is made of standard windows the use of standard doors is more common (93% of the area of residential building; see Table 29).

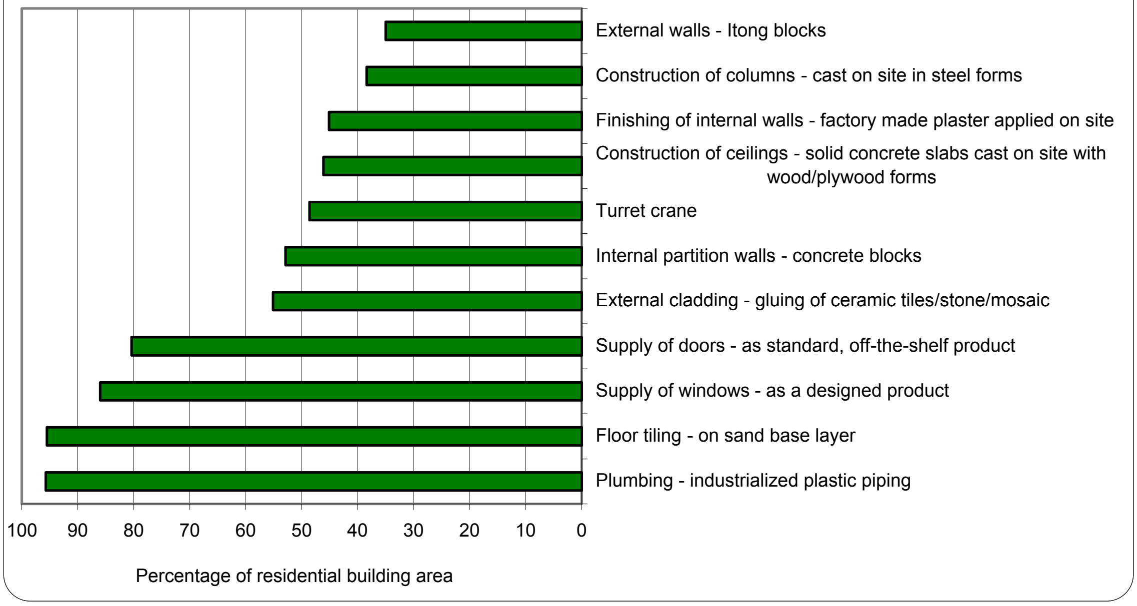
Summary of the Findings

The building technologies used for constructing the residential buildings generally vary with the characteristics of the building and the project. In high residential buildings use is usually made of industrialized technologies, which require less labour input per building unit, while in low-rise buildings conventional technologies are more common, which require more labour input. However, regarding floor tiling, plumbing, and doors and windows, there is a dominant method for all the buildings (see Table A).

The size of the project influences the choice of the building technology, in a similar way to the height of the building. In large projects, in which many dwelling units are constructed, industrialized technologies are more common, while in relatively small projects conventional technologies are more common (see Table B).

Diagram 1 presents the construction technology most widespread in residential building, for the major elements.

Diagram 1: The Most Common Construction Technologies, by Residential Building Elements



Conventional building technologies, which require considerable labour input per building unit, are commonly used for floor tiling (floor tiling on sand base layer is used for 96% of the area of residential building), supplying windows (as a designed product – 86%), for constructing internal walls (from concrete blocks – 53%), and for constructing external walls (using Itong blocks – 35%).

Medium level industrialized building technologies, which require average labour input per building unit, are commonly used for cladding external walls (gluing of ceramic tiles/stone/mosaic – 55% of the area of residential building), for constructing ceilings (solid concrete ceilings cast on site using wood/ plywood forms only – 46%), for cladding internal walls (factory-made plaster applied on site – 45%), and for constructing columns (columns cast on site in steel forms – 38%).

Industrialized building technologies, which require minimal labour input per building unit, are commonly used for installing plumbing (industrialized plastic piping – 96% of the area of residential building) and for supplying doors (standard off-the-shelf product – 80%).

Table A.- Most Widespread Technologies, by Height of the Building

The percentages are the percentage of the total area of the buildings in the storeys group

	Number of storeys in the building				
	1-5	6-10	11-15	16-20	21+
Mechanization on the site	Telescopic fork-lift	Turret crane	External elevator		
	39%	73%	52%	84%	83%
Columns	Cast on site in wood/plywood forms	Cast on site using steel forms			
	51%	38%	50%	67%	61%
Ceilings	Solid ceilings cast on site with wood/plywood forms		Solid ceilings – skins + additional casting	Solid ceilings cast on site with wood/ plywood forms	Solid ceilings – skins + additional casting
	59%	42%	38%	40%	59%
External walls	Itong blocks		Concrete walls cast on site with external and internal finish		Concrete walls cast on site with external finish
	41%	42%	30%	44%	32%
External cladding	Gluing of ceramic tiles/ stone/mosaic		External cladding made during production of the wall		
	53%	70%	53%	81%	80%
Internal walls	Concrete blocks		Plaster blocks		Plaster-board
	69%	55%	33%	36%	43%
Internal cladding	Factory-made plaster applied on site			Gluing plaster-board	Factory-made plaster applied on site
	51%	43%	49%	49%	41%
Floor tiling	Floor tiling on sand base layer				
	97%	94%	99%	96%	80%
Plumbing	Industrialized plastic piping				
	97%	95%	91%	100%	100%
Windows	As a designed product				
	84%	88%	81%	88%	100%
Doors	As standard off-the-shelf product				
	78%	85%	83%	64%	65%

Table B.- Most Widespread Technologies, by Number of Dwelling units in the Project

The percentages are the percentage of the total area of the buildings in the project group

	Number of dwelling units in the project				
	1-99	100-199	200-299	300-399	400+
Mechanization on the site	Turret crane				External elevator
	47%	54%	47%	57%	66%
Columns	Cast on site in wood/plywood forms	Cast on site in steel forms		No columns (only load bearing walls)	Cast on site in steel forms
	42%	46%	36%	51%	48%
Ceilings	Solid ceilings cast on site with wood/plywood forms		Solid ceilings cast on site	Solid ceilings cast on site with wood/ plywood forms	Solid ceilings cast on site with metal forms
	50%	51%	49%	48%	31%
External walls	Itong blocks	Concrete walls cast on site with external and internal finish	Itong blocks	Concrete walls cast on site with external finish	Pre-cast walls
	46%	27%	26%	56%	38%
External cladding	Gluing of ceramic tiles/ stone/mosaic	Made during production of the wall	Gluing of ceramic tiles/ stone/mosaic		Made during production of the wall
	62%	48%	60%	48%	59%
Internal walls	Concrete blocks		Plaster blocks	Concrete blocks	Plaster blocks
	66%	42%	39%	35%	25%
Internal cladding	Factory-made plaster and applied on site			Plasterboard or cement board	Factory-made plaster and applied on site
	50%	38%	42%	61%	42%
Floor tiling	Floor tiling on sand base layer				
	96%	95%	96%	91%	96%
Plumbing	Industrialized plastic piping				
	94%	98%	99%	93%	100%
Windows	As a designed product				
	90%	76%	88%	100%	81%
Doors	As an off-the-shelf (standard) product				
	76%	91%	85%	71%	79%

Table C.- Distribution of all the area, by percentages

	Total
Total	**100.0**
Storeys in building	
1-5	38.6
6-10	40.8
11-15	11.5
16-20	7.2
21+	1.9
Size of building (m^2)	
0-3,499	54.7
3,500-6,999	24.5
7,000-10,499	7.4
10,500+	13.4
Number of dwelling units in building	
1-24	49.7
25-50	29.4
50+	20.9
Building initiator	
Private	64.5
Public	35.5
District and area	
Jerusalem, Southern, Judea and Samaria and the Gaza area	34.5
Haifa and Northern	12.9
Tel Aviv and Central	52.6
Number of dwelling units in project	
1-99	55.5
100-199	26.2
200-299	8.4
300-399	4.4
400+	5.5
Method of construction	
Without repeated buildings	50.6
With repeated buildings	49.4
Constructor size	
Small (groups 1-2)	12.8
Medium (groups 3-4)	11.2
Large (group 5)	74.5
Unknown	1.5
Slope of the Area	
Level (less than 7%)	66.7
Inclined (7%-12%)	17.8
Steep (over 12%)	15.5
Ownership of the land	
Private	44.4
State	50.3
Other ownership	5.3
Framework for obtaining land	
A combination deal	11.8
Land tenders	43.2
Price tender for tenant, registration and lottery	5.7
Other	39.3

5. Reliability of the Estimates

The estimates presented in this publication are based on a sample survey, and may thus be subject to two main types of errors:

Sampling errors: These errors are due to the fact that the survey investigated only a sample of buildings, and not all the buildings in the survey population.

Non-sampling errors: These errors result from other factors that may be present even when a full census of the entire population is conducted.

5.1 Sampling errors and their application

The survey sample is one of many possible samples of the same size that could have been drawn from the same population by the same method.

The estimate $(\hat{X})$ is the value, estimated from the specific sample of this survey, of the corresponding value *X* that would have been obtained if a full census had been conducted.

The sampling error of the estimate $\sigma(\hat{X})$ is a measure of the variability between the different values of the estimate that would have been obtained from all possible samples of the same size and the same method, and the value that would have been obtained if a full census had been conducted under the same data-collection conditions.

The relative sampling error of the estimate is $\sigma(\hat{X})/\hat{X}$.

The confidence interval for the estimate is a range that contains the census value *X* at a given level of confidence. On the basis of the sample, estimates of sampling errors and relative sampling errors were calculated in addition to the estimates themselves.

The estimate $\hat{X}$, based on the sample, and the estimate of its sampling error $\hat{\sigma}(\hat{X})$, are presented in separate tables and make it possible to construct a confidence interval that contains the census value *X* at a predetermined confidence level.

If α is the stipulated confidence level, then the confidence interval at this level of confidence is obtained by $\hat{X} \pm K(\alpha) * \hat{\sigma}(\hat{X})$, according to the table:

α	67%	80%	90%	95%	99.5%
K(α)	1.0	1.3	1.7	2.0	2.8

Example 1: The estimated percentage of a building area, where the method used for constructing internal partition walls was concrete blocks, is 68.8% in buildings with 1-5 storeys (see Table 15). The sampling error for this estimate is 4.8% (see Table 16).

If a high confidence level of 95% is desired, the sampling error should be multiplied by 2 (K(α)=2.0). In this example, the confidence interval will be: 68.8±[4.8*2.0] = 68.8±9.6.

It can therefore be stated with a high level of confidence (95%) that the percentage of the building area, where the method used to construct internal partition walls was concrete blocks, in buildings with 1-5 storeys, ranges from 59.2% (68.8-9.6) to 78.4% (68.8+9.6).

<u>Notes</u>:

In order to warn the reader against using estimates that are subject to high errors, estimates with relative sampling errors between 25% and 40% are shown in parentheses ( ). When the estimates have very low reliability, with relative sampling errors greater than 40%, 2 dots are shown in place of the value of the estimate, as follows: "..".

When no units with the stipulated properties were sampled, the sampling error could not be calculated. In these cases, the symbol "-" appears in the table, with no sampling error.

Comparison of estimates related to mutually exclusive groups: Sampling errors can be used to compare estimates related to two mutually exclusive groups (e.g., a private initiator and a public initiator), and to determine whether the difference between the two groups is statistically significant. If the estimates for Group 1 and Group 2 are $\hat{X}_1$ and $\hat{X}_2$, respectively, then the estimate for the difference between the groups is $\hat{D} = \hat{X}_1 - \hat{X}_2$.

The sampling error of the estimated difference can be calculated as follows:

$$\hat{\sigma}(\hat{D}) = \sqrt{(\hat{\sigma}(\hat{X}_1))^2 + (\hat{\sigma}(\hat{X}_2))^2}$$

where $\hat{\sigma}(\hat{X}_1)$ is the sampling error of estimate $\hat{X}_1$, and $\hat{\sigma}(\hat{X}_2)$ is the sampling error of estimate $\hat{X}_2$. The confidence interval for the difference *D* at a confidence level of 95% is estimated as follows: $\hat{D} \pm 2\hat{\sigma}(\hat{D})$.

If the confidence interval contains the value 0, the difference is not statistically significant. In other words, on the basis of the specific sample in the survey, it **cannot be inferred** at a 95% confidence level that X_1 is different from X_2 in the population itself (even though the two values are different in the sample).

If the confidence level does not contain the value 0, it can be argued at a 95% confidence level that there is a statistically significant difference between the two groups, and the difference will be between $\hat{D} - 2\hat{\sigma}(\hat{D})$ and $\hat{D} + 2\hat{\sigma}(\hat{D})$.

Example 2: The estimated percentage of building area where the tower crane is the mechanization on the site, in buildings with up to 24 dwellings, is 39.2%; and the estimated percentage of building area in the same size of building where the telescopic fork-lift is the mechanization is 33.3% (see Table 1). The estimated difference is $\hat{D} = 5.9$. The sampling errors of the estimates are: 3.6 for tower crane mechanization, and 4.1 for telescopic fork-lift mechanization.

Based on the above formula, the sampling error of the estimated difference is:

$$\hat{\sigma}(\hat{D}) = \sqrt{3.6^2 + 4.1^2} \cong 5.5.$$

Therefore, a 95% confidence interval for the difference is 5.9 ± 11.0. Because the confidence interval contains the value 0, the difference between the estimates is not significant.

5.2 Non-sampling errors

The obtained estimate and its sampling error make it possible to deduce the census value. However, this value may be different from the real value for the population because it may be affected by non-sampling errors, which are difficult, if not impossible, to estimate. The estimates obtained from the "Survey of Residential Building Technologies in Israel 2003" may also be subject to different types of non-sampling errors, such as:

- **Response errors:** The survey estimates are subject to response errors, due to several factors that may bias the estimates in different directions. This may happen notwithstanding various tests that are performed in the course of constructing the questionnaires and in the course of data processing, which aim to reduce those errors. For example, the information provided by the interviewees is subject to response errors stemming from lack of accurate knowledge regarding all of the data that were collected, as well as by misinterpretation of the questions or by reluctance to provide accurate data.
- **Processing errors:** In the various stages of processing, which include data entry and logical checks, there is potential for errors that affect the reliability of the estimates.