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MATERIAL, LABOUR, CAPITAL and FLOW INPUTS of CONSTRUCTION IN THE SOVIET UNION

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MATERIAL, LABOUR, CAPITAL AND FLOW INPUTS IN CONSTRUCTION IN THE SOVIET UNION

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For The Research and Evaluation Division

Centre for Industrial Development

OUTLINE

Section I

Method and Scope

Summary

The general methodology of input/output analysis of Soviet construction is seen as follows:

A. Determination of input requirements for specific components of construction.

B. Preparation of a set of "representative" types of buildings and structures.

C. Determination of distribution of construction components as specified under A per unit of measurement (1,000 m^3 or 1,000 m^2) of representative types of buildings as specified under B.

The present study covers A above, that is the analysis of construction processes and determination of material, labor,capital and flow input requirements of specified construction components.

Method and Scope

Generally speaking this study covers industrial construction (promyshlennoe stroitel'stvo) in the USSR in the 1955-60 period. However, the end result of the study, that is the set of tables showing material, labor, capital and flow inputs requirements of specified construction components is equally applicable to residential and municipal construction. The distribution of processes differs in industrial and residential construction as shown in Table 1 but these differences would not affect the input flows to any significant degree. However, these must be taken into the account (by proper statistical weighting in averaging) for the purposes of determination of distribution of construction components.

Table 1

Percent distribution of construction processes according to labor expenditures in industrial and residential construction.

Process	Industrial Construction	Residential Construction
Earth and ground work	8–15	4–5
Carpentry	5–9	15–20
Masonry	6–8	6–10
Concrete and reinforced concrete work	10–18	1–3
Assembly of steel structures	3–8	0.5–1
Finishing	8–10	18–22
Transportation	6–8	8–12
Other processes	25–40	35–40

Source: Ukhov, p. 23

A reference to Table 1, Section II, will show that in terms of distribution of construction materials the industrial and residential construction are even more similar.

The choice of construction components(1). For the purposes of this study a construction project (a building or a structure) is broken down into components. A construction component is an intermediate product of construction activity; a "building block" of the final construction project. To facilitate the breakdown of a project into components the latter is defined in units of a homogeneous product, i.e., cubic meters of a brick wall or tons of structural steel, etc. The components are then grouped in classes (i.e., walls and enclosures). Presumably no substitution of one component of a given class for another component of a different class is

(1) Breaking down of buildings or structures into components is typically used in preparing the cost estimates of construction. It has also been suggested by the Stanford Research Institute in their study of Soviet construction (Norman Kaplan, A Comparison of Construction Costs in the USSR and US, Rand Corp., Santa Monica, Calif.: 1957)

possible while substitution within classes is. The choice of classes of components as well as components within classes has been dictated by the availability of Soviet data, by the nature of inputs (homogeneity of "input-mix") and by the overall nature of construction activities. Presumably the set of components as presented in this study would suffice to cover any building or structure of an industrial, commercial or residential type excluding only such special types as blast furnaces or oil refineries. Road, railroad, and harbor facilities construction are not covered in this study.

Following construction component classes were chosen:

- Foundation (6 components)
- Walls and enclosures (7 components)
- Reinforced concrete and metal skeleton frames (6 components)
- Columns, ceilings, and pillars (9 components)
- Doors, windows, and skylights (6 components)
- Other structural elements (18 components)

Data used. The inputs requirements of the various construction components are based on adjusted and modified Soviet "consolidated" data (ukrupnennye normy). The consolidated inputs requirements as presented in Soviet sources(1) show total input in all direct and auxilliary construction processes. Unfortunately the sources available (I. A. Petrov, volumes 1 and 2) were published in 1945. It has been noted, however, that the same data was still used in 1954(2). Throughout the study these 1945 inputs requirement were adjusted whenever possible for higher productivity capital equipment and/or more intensive use of capital equipment. For adjustment purposes official specific norms and other sources were used including some comparative U.S. data.(3) Furthermore it was necessary to adjust

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(1) For definition, construction and use of consolidated data in Soviet cost estimation see N. Pentkovskii, pp. 83-87

(2) Ukhov, pp. 76-78

(3) R. L. Peurifoy (2)

the components as given by Soviet sources, sometimes aggregating and averaging similar components and sometimes introducing new components. These adjustments are described in respective sections covering different component classes (Sections IV - IX).

Inputs. For the purposes of this study the various inputs used in construction are subdivided into material, labor, capital and flow inputs. These are defined and discussed in Sections II and III, as well as in the Appendix on capital equipment.

Notes:

1. The metric system of measurement is used.
2. Transliteration of Russian titles and names follows the rules adopted by the U. S. Library of Congress.
3. The bibliography shows all Soviet sources referred to in this study as well as few other sources which were consulted and used without specific references.

Section II

Material inputs

For the purposes of this study material inputs are defined as materials used in construction which after being machined, shaped, formed or fabricated become an integral part of a construction component. Material inputs are thus distinguished from flow inputs which are used in conjunction with construction machinery or labor and the level of utilization of which depends on the level of utilization of machinery or labor (e.g. fuel, electrical power, compressed air, etc.).

Construction industry is using an infinite number of various materials of different types, shapes, classes, etc. and some aggregation is necessary. Table 3 shows the material inputs used in this study. In most cases a whole range of construction materials has been reduced to one representative input. Thus Soviet sources distinguish between river sand, mountain sand and sea sand while this study shows sand, average, mineral, with the average weight of 1500-1600 kg/m^3 (see below). However, slag sand has been retained as a separate input because of its radically different weight (900 kg/m^3) and the fact that it is used for different purposes (e.g. for "light" concrete mixtures).

When applicable it has been also assumed that the material input shown is of average tensile strength, resistance to wear, resistivity, specific gravity and/or volume and with average moisture content. Specific gravities shown under "Notes" in Table 3 are averages and are used in calculations of transportation and storage input requirements.

All material inputs shown in various tables in this study give the gross weights and/or volume. That is losses and waste of materials in storage, transportation or due to accidental spoilage or breakage are included. However, for the purposes of later studies and comparison some data on utilization of construction materials are given.

The over-all importance of different material inputs can be judged from the following data.

Table 1

Percent breakdown of total weight of different materials used in construction.

Material	Industrial Construction	Residential Construction	For construction as a whole
Stone	14	11	13
Gravel, rubble	14	6	11
Sand	28	20	26
Brick and wall blocks	19	38	25
Cement	5.3	1.5	4.1
Lime	1.0	2.3	1.5
Gypsum	0.2	0.7	0.4
Lumber-all	8.5	14.0	10.0
Metals-all	4.0	0.5	3.0
Other materials	6	6	6

Source: R. N. Merkushev, p. 13

Table 2

Losses in construction materials due to spoilage, breakage, loss in storage or transportation

In percent of total weight/volume of material used

Lumber - all		5%
Nails		2%
Wire - construction		2%
Tar paper		5%
Fillers		4%
Brick - walls		4%
Mortar		2%
Paints		5%
Shingles, quarrystone		4%
Concrete		2%
Concrete mixing -	cement	1%
	Lime	2%
	clay	10%
	sand	5%
Forgings		3%
Steel-reinforcement		3%
Steel-structural & Profile		4%
Steel-sheet		2%

Source: L. A. Kaspin

Table 3

Material Inputs Used in Construction

Input	Unit of Measurement	Notes
Alabaster	m^3	Gypsum, A.W. 1,200 kg/m^3
Asphalt	tons	Bitumen, A.W. 1050 kg/m^3
Asbestos	kg	
Asphaltic putty	tons	
Blocks, concrete	m^3 or tons	Various sizes, Types gravel, rubble or slag
Bolts, nuts, washers	kg	
Brick, common	m^3	Sand-lime type, A.W. of one - 4 kg; A.W. 1800 kg/m^3 size 250mm x 120mm x 65mm
Brick face veneer	m^3	A.W. 1800 kg/m^3
Brick - hollow	m^3	A.W. 1300 - 1500 kg/m^3
Cement-Portland	tons	A.W. 1300-1700 kg/m^3
Clay	m^3	
Clay filler	m^3	Porous, A.W. 450-700 kg/m^3 A.W. 1900 kg/m^3
Concrete	m^3	Brick rubble. Cement 200-350 kg; brick rubble 0.8m^3; sand 0.4-0.5m^3; water 230 liters per m^3
Concrete	m^3	Gravel. A.W. 2300 kg/m^3 Cement 200-350 kg; gravel 0.8 m^3; sand 0.4-0.5m^3 water 210 liters
Concrete	m^3	Slag. A.W. 1550 kg Cement 280-290 kg, slag 0.68m^3, slag sand 0.6 m^3, water 250
Eternit	1000 units	Asbestos-cement roofing material
Felt, felting	kg	
Forgings	tons	Pins, spikes, cotters, hooks, braces, frames, cramps, shafts
Glass	m^2	Window. 6-10 kg/m^2
Gravel	m^3	1800 kg per 1m^3
Lime	tons	Slaked. A.W. 500-600 kg/m^3
Lumber-round	m^3	D: up to 24cm, L: 4-7m A.W. 600-700 kg/m^3 Moisture content max. 20%

Table 3 (cont'd.)

Input	Unit of Measurement	Notes
Lumber-sawed	m^3	L: 4-7cm; T: 3-5cm A.W. 600-700 kg/m^3 Moisture content, max. 15%
Mortar-cement	m^3	Heavy. 250-480 kg of Portland cement 1.03 m^3 of sand, 300 liters of water per m^3
Mortar-cement	m^3	Light. 220 kg of Portland cement, 0.13 m^3 of lime, 1.22 m^3 of slag sand, 250 liters of water per m^3
Mortar-lime	m^3	0.33 m^3 of lime; 1 m^3 of sand, 200 liters of water
Nails	kg	All type wire nails, construction
Quarrystone	m^3	A.W. one stone 20-40 kg A.W. 1750 kg per m^3
Quicklime	m^3	Calcium oxide. A.W. 500-600 kg/m^3
Paint-Iron Oxide	kg	
Paint-oil	kg	
Paints-other	kg	
Pergamyn	m^2	Parchment paper
Plywood	m^3	A.W. 700 kg/m^2
Rubble	m^3	Brick
Ruberoid	m^2	
Sand	m^3	Mineral, A.W. 1500-1600 kg/m^3
Sheet iron	unit	Roofing tin
Shingle	m^3	Cobblestone. 1800 kg per 1 m^3
Slag	m^3	A.W. 700-1000 kg/m^3
Slag sand	m^3	A.W. 900 kg/m^3
Steel, reinforcing	tons	Hot rolled steel; shapes: bars, wire, cages and fabric
Steel-structural	tons	Hot rolled carbon steel, open-hearth or Bessemer. Also low-alloy steel. Various profiles and girders (e.g. H columns, I and WF beams, channels, angles and plates)
Tar	tons	
Tar paper	m^2	Asphaltic
Wire	kg	
Whiting	m^3	Chalk. A.W. 950-1200 kg/m^3

Section III

Labor, Capital, and Flow Inputs

Labor

Labor input requirements are presented in terms of man-hours per unit of specified construction component. The labor input requirements are shown for productive workers only ("proizvodstvennye rabochie") which comprise for construction as a whole from 83 to 87% of the total number employed. The overall distribution of employed is shown on Table 1.

Table 1

Percent distribution of construction employment

Productive workers	85.0%
Engineers & technicians	5.5%
Clerical personnel	6.0%
Auxilliary personnel[(1)]	3.5%

Source: Nebol'sin, p. 239; Statistical Yearbook for 1960, p. 626

The study does not distinguish between various professions and/or different skills. For comparison purposes and for further study the absolute and the percent distribution of construction workers in the USSR is given in Table 2.

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(1) Night watchmen, guards, etc. defined in the USSR as "mladshii obsluzhivaiushchii personal" - auxilliary service personnel.

Table 2

Distribution of Productive Workers by Professions in Soviet Construction in 1959

	Number	Percent
Power shovel operators	124,000	2.4
Operators of other construction machinery	116,500	2.3
Manual workers, earth work	180,300	3.5
Masons, bricklayers	741,900	14.6
Carpenters	2,092,000	41.1
Plasterers	518,900	10.2
Painters	430,000	8.4
Furnace layers	123,600	2.4
Others	767,000	15.1
Total	5,094,200	100.00

Statistical Yearbook, 1960, p. 30

The average number of work days per year in the Soviet Union in construction can be approximately estimated to be 285 (1). This figure is the total "work fund" available net of sick days, annual leaves, and other absences from work.

The derivation of specific labor input requirements is shown in respective sections below.

Capital

Capital input requirements are presented in terms of machine-hours of actual work performed. Specific input requirements are discussed in respective sections. It must be noted that due to deficiencies of Soviet data the machine-hours requirement as shown in this study are somewhat underestimated. In addition to specific machines discussed in connection with various components below Appendix 1 presents data on major groups of capital equipment used currently in the USSR as well as some discussion of utilization of machinery.

(1) Shass, p. 432

It must be noted that all input requirements presented for specific construction components are based on the assumption that all the construction materials needed were brought, unloaded and stored in the immediate vicinity of the construction site. Thus the transportation work accounted for in this study is loading and hauling away of residual earth and transportation (in many instances manual) of construction materials at the project site.(1) The capital input requirements of transportation of construction materials to the construction site can be estimated at later stages of analysis.

Flow inputs

Flow inputs are defined as inputs the level of requirements of which depends on the level of utilization of machinery(2) used in construction. For the purposes of this study following flow inputs are taken into account:

Table 3

Flow Inputs

Input	Unit of measurement
Water	m^3
Compressed air	m^3
Electrical energy	KWH
Diesel fuel	kg
Gasoline	liters
Lubricants	kg

Calculation of specific flow inputs is discussed in respective sections.

(1) And all hoisting operations ("vertical transportation").

(2) Water presents the only exception as it could be classified with material inputs.

Section IV

Foundations

The design of and the materials used in foundations depend on structural characteristics of the building as well as on the nature and configuration of grounds. For the purposes of this study the following types[1] of foundations will be identified:

Table 1 [2]

No.	Main material	Design
F-1	Quarrystone	Columns
F-2	Quarrystone	Bands
F-3	Quarrystone-concrete	Columns
F-4	Quarrystone-concrete	Bands
F-5	Quarrystone-concrete	Solid base
F-6	Concrete blocks	Columns-Bands

The six types chosen deem to be representative of most types of foundations currently used. Wooden and temporary foundations are excluded from consideration under foundation components of construction. However, the material and flow inputs into wooden and temporary foundation of warehouses, storage bins, etc. are included under appropriate processes.

The various processes analyzed in foundation work are as follows: landscaping, excavation of earth, shoring trenches, removal of supports, protection from ground water, building, erection and removal of form panels, placing of stones, concrete and concrete blocks, curing of concrete, insulating, filling in by earth and removing of residual earth.

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(1) One important type of foundations, e.g., reinforced concrete foundations is excluded here and will be considered under reinforced concrete structures.

(2) Onufriev, pp. 284-293, Arbuzov-II, pp 46-52

Table Two

Material Inputs per 100 m^3 of foundations of specified type

Input	Unit	F-1	F-2	F-3	F-4	F-5	F-6
Blocks, concrete	T.	-	-	-	-	-	140
Cement, Portland	T	5.62	5.62	15.80	15.80	16.00	4.80
Concrete (with gravel)	T	-	-	(67)	(67)	(67)	-
Gravel	m^3	-	-	64.8	64.8	65.9	40
Lime (slaked)	T	3	3	-	-	-	-
Lumber, round	m^3	4.7	0.7	4.7	0.7	0.7	4.7
Lumber, cut	m^3	4.3	2.4	6.2	3.4	1.6	4.3
Mortar (cement)	m^3	(38)	(38)	-	-	-	
Nails	kg	20	5	35	17	18	20
Quarrystone	m^3	103	103	-	-	-	-
Sand (mineral)	m^3	40.3	40.3	29.2	29.2	29.4	10.0
Shingle(cobblestone)	m^3	-	-	45	45	45	-
Tar paper-asphaltic	m^2	108	108	108	108	108	108
Tar	T	0.19	0.19	0.19	0.19	0.19	0.19
Wire (construction)	kg	-	-	9	-	8	5

Notes and Sources Table II

Sources: For F-1 through F-5, A. Petrov-I, p.12; for F-2, Kuprianov, p.294

1. Values shown in parentheses mean that the corresponding material inputs were taken into account elsewhere in the table. It is still necessary to show these for subsequent calculations of labour, capital and flow inputs. However, for purposes of summing up of material inputs values in parentheses should be excluded.

2. For weight measures of materials given in volume measures see appendix.

3. The number and weight of concrete blocks used in foundations varies from 1.5 to 4 tons. An average type is used here.

It is much more difficult to derive average input coefficients of labour, capital and flow inputs into foundations and, consequently, the margin of error is considerable. While some substitution of material inputs is possible the choice of type of foundation components is such that it is negligible. Not so with labour and capital inputs. The range substitutability of capital for labour is especially wide in earth work and ground preparation. One power shovel depending on capacity of the bucket can replace from 100 to 7-8,000 men. An average bulldozer replaces about 200 workers[(1)]. The actual labour-capital ratio depends on the type and configuration of grounds, the overall size of the construction project and the type of work performed. The Soviets publish an index of mechanization of various construction processes which is defined as a ratio of the total volume of work to the volume of work performed by machinery-equipped labour. Thus, in 1958 in earth and ground work 94% of the total work was performed by machines[(2)]. The remaining 6% were performed by extreme labour-intensive method as shown by the fact that in the same year the ratio of "mechanized" labour to manual labour was 1:1.[(3)] (Thus, 50% of all production workers in earth and ground work completed 6% of total volume of earth and ground work). In loading-unloading and other auxilliary transportation processes 60% of the total volume of work is performed by machines, while the percent of manual labour is 70.

As with other input requirements the data on labour and capital in this study is based on consolidated ("ukrupnennye") indexes. The solution, by no means an ideal one, is as follows: the consolidated indexes are used and adjusted for present conditions whenever possible. Some of these adjustments are explained in Notes to Table 3.

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(1) Shass, p. 210.

(2) Statistical Yearbook, p. 625.

(3) Shass, p. 212.

Table Three

Labour, Capital and Flow Inputs per 100 m^3 of foundations of specified types

Input	Unit	F-1	F-2	F-3	F-4	F-5	F-6
Labour	man-hrs.	1,394	995	1,308	997	894	1,077
Capital equipment	mach. hrs						
Power shovels, capacity 0.3-1.0 m^3	"	10.8	9.5	10.8	9.5	9.5	10.8
Bulldozers, 52-84 HP	"	1.6	1.1	1.6	1.1	1.1	1.6
Trucks-dumpers	"	15.0	15.0	15.0	15.0	15.0	15.0
Hoisting equipment (2-5 tons)	"	-	-	-	-	-	21.0
Mortar mixers	"	12.2	12.2	-	-	-	3.2
Concrete mixers		-	-	18.6	18.6	18.6	
Flow inputs							
Water	m^3	43	26	165	150	155	110
Fuel-deisel	kg	101	86	101	86	86	270
Electrical Power	KWH	20	20	120	118	122	20
Lubricants	kg	6	5	6	5	5	16
Gasoline	l	93	93	130	130	130	39

Notes and Sources, Table 3

F-1 through F-5; I. A. Petrov, p. 12 and p. 156; F-6: Kaspin, p. 124. The input coefficients have been considerably revised and adjusted. The consolidated indexes for F-1 through F-5 as given in I. A. Petrov are for 1945 and had to be adjusted for increased use of capital equipment in construction.

Thus, the capital and labour requirement were completely revised as shown in following auxilliary tables.

Table 3A

Requirement for earth and ground work per 100 m^3 of foundations of specified type

	Unit	F-1	F-2	F-3	F-4	F-5	F-6	
I. Excavation of earth - total	m^3	400	300	400	300	300	400	1
of which excavation by machines	m^3	240	210	240	210	210	240	2
Machine time required	mach-hr	10.8	9.5	10.8	9.5	9.5	10.8	3
Labour to operate machine	man-hr	22	19	22	19	19	22	4
Of which excavated by hand (1-2)	m^3	160	90	160	90	90	160	5
Manual labour required	man-hr	320	196	320	196	196	320	6
II. Filling-in of earth - total	m^3	300	200	300	200	200	300	7
of which filled in by machines	m^3	210	140	210	140	140	210	8
Machine time required	mach-hr	1.6	1.1	1.6	1.1	1.1	1.6	9
Labour to operate machines	man-hr	1.6	1.1	1.6	1.1	1.1	1.6	10
of which filled in by hand (7-8)	m^3	90	60	90	60	60	90	11
Manual labour required	man-hr	120	80	120	80	80	120	12
III. Removal of earth and other operations	m^3	100	100	100	100	100	100	13
of which removed by trucks	m^3	70	70	70	70	70	70	14
Machine time required	mach-hr	15	15	15	15	15	15	15
Labour to operate machines	man-hr	15	15	15	15	15	15	16
of which worked by hand (13-14)	m^3	30	30	30	30	30	30	17
Manual labour required	man-hr	60	60	60	60	60	60	18
Total for manual labour (6+12+18)	man-hr	500	336	500	336	336	500	19
Total for labour to operate machines(4+10+16)	"	40	35	40	35	35	40	20

Notes and Sources to Table 3A

Earth and ground work requirements are estimated from following sources:
I.A. Petrov-I, p. 9, Ukhov, pp 186-187, N. Arbuzov-II, pp 246-247

Manual labour requirements as shown in Table 3A are based on following estimated averages:

Manual earth excavation, average type earth - 4 m^3 per 8 hrs.
Manual filling in and packing of earth - 6 m^3 per 8 hrs.
Manual loading on trucks of removing - 4 m^3 per 8 hrs.

All of these estimates are averages from tables shown in Kaspin, pp. 91-119

Requirements of machine-time of capital equipment and labour-time to operate these machines are based on Table 3B:

Table 3B

Labour, Capital and Flow inputs requirements per 100 m^3 of earth and ground work

Process	Equipment	Machine Hours	Man Hours
1. Ground excavation, loading of earth on trucks. Average type earth	Power shovel, caterpillar type, capacity of bucket 0.25 - 1.00 m^3	4.44	8.88
2. Same	Capacity 1.00-2.00 m^3	1.48	2.96
3. Same	Draglines, caterpillar, capacity 0.25-1.00 m^3	4.81	9.62
4. Same	Trenching machines, all types	2.46	4.92
5. Earth moving. Up to 100 m. Average earth	Scrapers, all type	6.00	6.00
6. Same	Bulldozers, 52-84 HP	1.70	1.70
7. Filling in of trenches	Bulldozers, 52-84 HP	.75	.75
8. Earth grading, path 25m	Graders, 52-80 HP	2.50	5.00
9. Earth packing (per 1000 m^2)	Rollers, all types	.60	.60
10. Hauling away of earth on dumper trucks loaded by power-shovels (0.25-2.0 m^3) for 5 km. Average type dirt roads	Trucks, dumpers 2-3 tons capacity	21.0	21.0

Sources, Table 3B -

L. A. Kaspin, pp 71-90; A. Vainson, pp. 357-390; Onufriev, pp. 436-462

Flow inputs are adopted from I.A. Petrov, p. 12 and adjusted for additional use of capital equipment.

References - Fuel (diesel) - Onufriev, pp. 482-483
Lubricants - (ibid) pp. 486
Gasoline - (ibid) pp. 484

Section V

Walls and Enclosures

Walls and Enclosures components as defined for the purposes of this study are shown in Table 1. Again, as with other components homogeneity of the component group as well as the similarity in material and other inputs are the main criteria of classification.

Table 1

Walls and Enclosures

No.	Main material	Design
W-1	Quarrystone	For basement walls. Without face bricks
W-2	Quarrystone	For basement walls. With face bricks
W-3	Common brick	Outside walls and enclosures. Simple architectural design. Warm mortar
W-4	Common brick	Same as W-3. Complex architectural design.
W-5	Common brick with filler	Complex architectural design
W-6	Cement blocks (small)	
W-7	Ceramic blocks	Faced with 1/2 brick

For classification purposes Soviet consolidated construction data used is adjusted for newer type structures (e.g. W-7 - ceramic blocks faced with brick). The building processes[1] analyzed for the purpose of construction of input tables are as follows:

For Quarrystone walls - masonry and stonework, water proofing, installation of insulation materials. Facing of walls with bricks, preparation of mortar. Erection and removal of forms and scaffolds.

For brick and block walls - masonry work with installation of steel supports (if used). Filling in of materials (for W-5). Preparation of mortar and/or concrete. Erection and removal of scaffolds.

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(1) As with all other components the necessary materials have been brought to the vicinity of the construction site.

Table 2

Material Inputs per 100 m^3 of walls and enclosures of specified type

Materials	Unit	W-1	W-2	W-3	W-4	W-5	W-6	W-7
Brick, common	1000u	-	0	38.6	40.6	31.1	-	14
Blocks, ceramic	1000u	-	-	-	-	-	-	13
Blocks, concrete	tons	-	-	-	-	-	145	-
Cement, Portland	tons	4.5	4.3	4.6	4.6	8.4	2.5	-
Concrete, Slag	m^3	-	-	-	-	(37)	-	-
Lime (slacked)	m^3	5.5	5.2	2.6	2.6	1.3	1.4	1.5
Lumber (sawed)	m^3	-	-	1.0	1.5	1.5	1.5	1.0
Mortar-lime	m^3	(38)	(30)	(31.5)	(31.5)	(15.6)	(17)	(19.4)
Nails	kg	-	-	7	7.5	7.5	7.5	7.0
Quarrystone	m^3	103	81	-	-	-	-	-
Tar	tons	0.1	0.1	-	-	-	-	-
Tar paper	m^2	80	80	-	-	-	-	-
Sand	m^3	40.3	38.2	-	-	-	-	-
Slag sand	m^3	-	-	32.1	32.1	15.9	17.3	23.7
Slag	m^3	-	-	-	-	50	-	-
Steel (structural)	tons	-	-	.09	.10	0.16	-	0.1

Sources:
W-1 through W-6: I. A. Petrov, p. 16-19, W-7, L. Kaspin pp. 253-296.
Note: As with foundations quantity of concrete and mortar are shown in parentheses because all the necessary ingredients (e.g. lime, sand, etc.) are shown elsewhere in the table.

Table 3

Labor, Capital and Flow Inputs per 100 m^3 of walls and enclosures of specified type

	Units	W-1	W-2	W-3	W-4	W-5	W-6	W-7
Labor	man-hr	760	780	950	1130	1260	800	1200
Capital equipment								
Hoisting and transportation(vertical)								
1.Crane (capacity 0.5 tons, speed 0.25 m/sec; power rating 3.2 KW	mach.hr	-	-	2.0	2.0	2.0	2.0	2.0
2.Shaft lift (capacity 1 ton;speed 0.65 m/sec;power rating 9.1 KW	"	-	-	3.0	3.0	10.0	2.0	2.0
3.Cantilever, (or conveyor)	"	10.0	10.0	16.0	16	12	17	12
Masonry equipment								
1. Concrete mixer (100-200 l.capacity)	"	-	-	-	-	8.9	-	-
2. Mortar-mixer (150 l. capacity)	"	14.8	14.0	12.3	12.3	6.1	6.6	7.6
3. Riddles	"	7	6.5	-	-	7.4	-	-
Flow inputs								
Water	m^3	21	20	17	17	24	6	12
Lubricants	kg	1	1	1	1	2	1	1
Electrical energy	KWH	40	40	120	120	150	60	70

Sources and Notes, Table 3

For W-1 through W-6, I. A. Petrov, p. 16, p. 158

For W-6 and W-7, L. Kaspin, pp. 253-296

Notes:

1. For detail description of capital equipment see Appendix.

2. Data in Petrov had to be adjusted to take into the account technological progress and the greater use of machinery in construction. The adjustment of labor requirements is, however, not very significant. Masonry work has remained essentially on the same level of labor utilization for the last 10-15 years.

Processes which are partially mechanized now are mortar and concrete preparation (mixing) and vertical transportation of materials.

3. Table 3A shows the detail analysis of concrete preparation. The corresponding input coefficients shown in Table 3 above are based on this data.

Table 3A

Preparation of Concrete

Material, labor, capital and flow inputs per 10 m^3 of concrete

Inputs	Units	Heavy	Heavy	Light	
Material Inputs					
Portland Cement	tons	2.7	2.9	2.9	1
Gravel	m^3	8.4	-	-	2
Rubble (brick and other)	m^3	-	8.6	-	3
Slag	m^3	-	-	8.6	4
Sand (mineral)	m^3	4.9	4.9	-	5
Sand (slag)	m^3	-	-	5.6	6
Capital inputs					
Concrete mixer, capacity 250-425 liters, (mixing time 1-4 minutes)	mach.hrs.	2.4	2.4	2.4	7
Screens (riddle) productivity s-10 m^3/hr.	mach.hrs.	3.1	3.1	2.0	8
Crusher, productivity 12-20 m^3/hr. diesel	mach.hrs.	-	1.7	-	9
Labor-to screen and crush materials, to load the mixer and to operate all machines (total)	man-hr.	26.7	28.5	17.9	10
Out of which:					
To load the mixer (max. distance of stored materials 10 m.)	man-hrs.	16.9	16.9	9.1	11
To operate the mixer	man-hrs.	2.8	2.8	2.8	12
To load and operate riddles and crushers	man-hrs.	7.0	8.8	6.0	13
Flow inputs					
Water (needed for concrete and washing of gravel and sand)	m^3	13.5	13.7	8.9	14
Lubricants	kg	1.5	2	1.5	15
Electrical power	KWH	16	20	15	16

Source: Table 3A, L. Kaspin, pp. 225-232, E. Kuprianov, pp. 320-323

Section VI

Reinforced Concrete and Metal Skeleton Frames

While reinforced concrete and metal frames differ significantly in terms of input-mix it is still deemed desirable to define both elements under the same class of components of construction. In doing this we are following the practice of Soviet cost estimates and consolidated ("ukrupnennye") construction data.

Table 1 shows the design, characteristics and materials of six major components.

Table 1

Reinforced Concrete and Metal Skeleton Frames

No.	Main material	Design and characteristics
S-1	Reinforced concrete	Industrial one-story high buildings without overhead heavy hoisting and/or transportation equipment. (Poured in place)
S-2	Reinforced concrete	Industrial one-story high buildings with overhead heavy hoisting and/or transportation equipment. (Poured in place)
S-3	Reinforced concrete	Industrial multi-story high buildings with reinforced concrete spans (ceilings). (Poured in place)
S-4	Steel	Steel skeleton frames with spans up to 15 m.
S-5	Steel	Steel skeleton frames with spans of more than 15 m.
S-6	Reinforced concrete	Industrial one-story high buildings, concrete spans, with heavy overhead cranes. (Pre-cast)

The work processes analyzed in terms of material, labor, capital and flow input requirements are as follows:

For reinforced concrete components: digging of holes and trenches, shoring of trenches, filling in and/or removal of residual earth. Placing of sand under wall beams and insulation of same. Erection and removal of scaffolds and forms. Preparation, fabrication and placing of reinforcing steel. Preparation, mixing, placing, finishing and curing of concrete.

For metal frame components: preparation of grounds, assembly and erection of structures. Preparation, mixing of concrete and placing of concrete around anchor bolts. Painting of frames.
For both types erection, rigging and dismantling of hoisting equipment is taken into account.

Shortcomings of the analysis

Unfortunately, the basic input requirement data used is from I.A. Petrov, a 1945 source. Since then there were significant changes in construction methods as well as in types of construction elements used. It was possible to account for the more efficient use of, and more productive types of hoisting and transportation equipment as well as for the partial mechanization of earth work.
However, other changes in methods and types were not reflected. Following should be noted:

1. Special types of plywood and sheet steel are used more and more extensively as materials for forms for concrete placing. The input requirements for concrete forms shown on tables 2 and 3 and elsewhere in the study are based mainly on the use of sawn lumber (boards, etc.).
2. Welding of reinforcing steel in now used more extensively while the input requirements are based mainly (but not exclusively) on use of tied and bent reinforcing steel.
3. The input requirements for assembly of metal skeleton frames shown in tables are based mainly on bolting of elements. Riveting and welding of steel frames is at present more extensive.
4. The three reinforced concrete components shown are of a "poured in place" type. That is concrete is placed in forms after these have been erected and assembled. A method by which the concrete is placed and cured on the ground and then the finished elements are erected is more extensively used now. To correct for this omission we have introduced in addition to five components adopted from I.A. Petrov a reinforced concrete component built by pre-case methods. (For details see Notes to Table 2 and 3). The source from which this component has been adopted is very detailed in terms of labor and machine-time requirements but gives no material requirements breakdown. These have been estimated from different sources and an error is possible.

Table 2

Material Inputs per 100m^3 of reinforced concrete or 100 tons of metal skeleton frames

Material	Unit	S-1	S-2	S-3	S-4	S-5	S-6
Asphalt (bitumen)	tons	0.3	0.3	0.2	-	-	0.2
Bolts	tons	-	-	-	.3	.33	-
Cement-Portland	tons	26.4	25.9	26.9	0.4	0.7	27.0
Concrete-gravel	m^3	(102)	(102)	(102)	(1.3)	(2.3)	(101)
Forgings	tons	-	-	-	.68	.53	-
Gravel	m^3	102	102	102	1.3	2.2	95
Lumber-round	m^3	5.1	4.4	10.0	21.5	14.5	3.0
Lumber-sawed	m^3	14.4	10.3	14.3	13.2	12.3	10.0
Nails	kg	165	123	202	1	2	80
Paint-Iron Oxide	kg	-	-	-	358.0	316.0	-
" -Oil	kg	-	-	-	158.0	139.0	-
" -Other	kg	-	-	-	5.3	4.7	-
Rubble (brick)	m^3	3.9	3.3	2.2	-	-	2.2
Sand-mineral	m^3	86.4	81.1	75.6	0.7	1.2	70.0
Slag	m^3	17.0	14.5	9.7	-	-	-
Steel-reinforcing-rolled	tons	3.1	3.6	4.7	-	-	110
-profile	tons	9.3	9.9	7.7	-	-	
Steel structural	tons	-	-	-	100	100	-
Tar paper	m^2	129	110	74	-	-	80
Wire	kg	61.6	69.5	61.6	-	-	50
Stands for concrete forms	units	-	-	-	-	-	1200

Source: I.A. Petrov, p. 20

Notes

1) S-6 component has been adopted from B.S. Ukhov, pp. 191-198 which describes work on a one story high industrial building with overhead cranes (10 tons) typical for machinery and assembly shops of machine building plants. The concrete elements of the building are prepared on the ground and then assembled. The overall concrete work covers:

132 columns, 8 tons each = 420 m^3 of concrete
110 girder trusses, 6 tons each = 220 m^3 of concrete
200 crane beams, 5 tons each = 400 m^3 of concrete
1,200 slabs, 1.2 tons each = 600 m^3 of concrete

for a total of 1,640 m^3 of concrete. Labor requirements are preparations - 1,380 man-days; preparation of concrete mixture, preparation of forms and reinforcing steel, pouring of concrete, removal of forms - 2,345 man-days; assembly of elements 709 man-days, for a total of 4,434 man-days. Estimation of reinforcing steel requirements based on M.S. Khutorianskii, pp. 217-221. Other material inputs requirement on L. Kaspin, p.228 and pp. 199-235.

Table 3

Labor, Capital and Flow Inputs per 100 m^3 of Reinforced Concrete of 100 tons of metal skeleton frames

	Units	S-1	S-2	S-3	S-4	S-5	S-6
Capital equipment	mach/hr						
Hoisting equipment	"						
Cranes (medium 1-3 tons)	"	-	-	30	-	-	
Cranes (large 3-20 tons)	"	-	-	-	35	45	41
Shaft or mast lifts	"	-	-	15	7	7	-
Booms or auto-cranes	"	20	20	10	25	25	15
Concrete equipment							
Concrete mixers (425 l. capacity) st.	"	6	6	6	-	-	6
Concrete mixers (100 l. capacity)	"	-	-	-	1	1	-
Other machinery (crushers, riddles, vibrators)	"	150	150	150	5	5	150
Other equipment							
Machine tools for steel reinforcements	"	20	20	20	-	-	20
Earth excavating and moving equipment	"	8	10	10	-	-	10
Labor	man-hrs	2720	2270	2690	6670	6080	2163
Flow inputs							
Water	m^3	231	231	266	40	90	260
Compressed air	$1000m^3$	-	-	-	30	32	-
Lubricants	kg	10	10	10	50	60	10
Electrical power	KWH	1000	1000	1000	1500	1500	2000
Fuel consumption	kg	70	80	80	30	30	80

Sources and Notes, Table 3

Sources: I.A. Petrov, pp 20-21, pp 159-160, Ukhov, pp 191-198

Notes

1. Estimates of hoisting equipment used - based on Appendix 1, section on hoisting equipment and sources cited therein.

2. Labor expenditure given in Petrov (pp 159-160) adjusted downward. For S-1, S-2, S-3 downward adjustment 20% since these processes include significant volume of earth and ground work. For S-4 and S-5 downward adjustment 10%.
3. Concrete equipment used - based on Appendix 1, section on concrete mixing equipment and sources cited therein.

Section VII

Columns, Ceilings (Spans), Pillars

This class of components covers most masonry and concrete elements of buildings not covered elsewhere in the study. Table 1 shows the main characteristics of components of this class.

Table 1

Main materials and design characteristics of columns, pillars and ceilings (spans)

No.	Main Material	Design
C-1	Brick	Rectangular pillars
C-2	Reinforced concrete	Columns-poured in place Area up to 0.2 m^2
C-3	Reinforced concrete	Columns-poured in place Area 0.2 - 0.4 m^2
C-4	Reinforced concrete	Columns-pre-cast Volume: less than 3 m^3
C-5	Reinforced concrete	Columns-pre-cast Volume: more than 3 m^3
C-6	Reinforced concrete	Ceilings (spans)-residential or public buildings
C-7	Reinforced concrete	Ceilings (spans)-industrial buildings
C-8	Reinforced concrete	Various concrete elements of masonry buildings
C-9	Wood	Ceilings (spans) all types

The work processes analyzed in terms of material and other input requirement are as follows:

1. For brick pillars (C-1), Mortar preparation, laying of bricks, preparation of reinforced concrete elements on top of columns (inc. preparation of concrete and reinforcing steel, placing and curing of concrete). Erection and removal of scaffolds.
2. For reinforced concrete columns (C-2 through C-5). Preparation, erection and removal of forms. Preparation and placing of reinforcing steel. Preparation of concrete, its placing and curing. Finishing. Assembly and erection of columns (for pre-cast columns only)
3. For ceilings (C-6 through C-8). Preparation, erection and removal of scaffolds and concrete forms. Preparing and placing of reinforcing steel. Preparation of concrete, its placing and curing. Finishing. (Assembly and erection for C-8)

4. For wooden ceilings (C-9). Preparation and placing of beams. Preparation of fillers and placing. Erection and removal of supports.

It will be noted that erection of ceilings does not cover preparation and laying of floors which is analyzed elsewhere in this study.

Tables 2 and 3 show material and other input requirements for these components.

Table 2

Material inputs per 100 m^3 of masonry or reinforced concrete or per 100 m^3 of wooden ceilings

Material	Unit	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9
Brick (common)	1000	43	-	-	-	-	-	-	-	-
Cement	tons	4	28.5	27.5	27.3	27.3	27.3	27.3	27.8	-
Clay	m^3	-	-	-	-	-	-	-	-	1.5
Concrete (gravel)	m^3	(3.7)	(102)	(102)	(110)	(110)	(101)	(101)	(101)	-
Forgings	kg	-	-	-	-	-	-	-	-	25
Gravel	m^3	3.8	102	102	109	109	101	101	101	-
Lime	tons	1.7	-	-	-	-	-	-	-	-
Lumber-round	m^3	-	-	-	0.2	0.2	-	-	19.1	8.0
Lumber-sawed	m^3	1.0	22.6	12.6	17.4	17.4	17.0	13.0	21.5	3.5
Mortar-lime	m^3	(21)	-	-	-	-	-	-	-	-
Nails	kg	18	247	104	79	79	145	115	218	23
Sand	m^3	24.2	59.3	56.5	59.8	59.8	56.2	56.2	57.5	
Slag	m^3	-	-	-	-	-	-	-	-	6.5
Steel, reinforcing-rolled	tons	0.22	2.0	2.0	2.31	2.31	4.3	4.7	2.8	-
-profile	tons	0.7	11.0	11.0	13.2	13.2	4.3	4.7	7.8	-
Stands	units		-	-	-	-	52	27	-	-
Tar	tons	-	-	-	-	-	-	-	-	0.16
Tar paper	m^2	-	-	-	-	-	-	-	-	25
Wire	kg	1	65	65	-	-	-	-	-	-

Source: I.A. Petrov, pp 22-23, p 25-26

Note: Material input requirements for wooden ceilings (C-9) shown were calculated as a simple arithmetic average requirement of 6 different types of wooden ceilings.

Table 3

Labor, Capital and Flow Inputs per 100 m^3 of masonry or reinforced concrete or per 100 m^2 of wooden ceilings.

	Unit	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9
Labor	man hrs	1325	2712	1864	1946	1900	2054	1798	2806	210
Capital	mach.hrs									
Concrete mixers, 425 l. capacity	"	-	24	24	24	24	24	24	30	-
Concrete mixers, 100-200 l. capacity	"	-	-	-	5	5	-	-	-	-
Other concrete/mortar mixing equipment	"	20	45	45	55	55	45	45	50	-
Cranes (1 - 3 tons)		-	-	-	25	25	-	-	25	-
Cranes (automobile)		-	20	20	-	-	20	20	-	20
Transporters (or cantilevers)		16	20	20	20	20	20	20	20	-
Flow inputs										
Water	m^3	28	193	160	175	161	185	185	178	-
Electrical power	KWH	75	1000	1000	900	900	900	900	900	60

Sources and Notes, I. A. Petrov, pp. 22-23, 25-26, 160-161

Notes: To account for higher labor productivity labor input requirements were adjusted downward: for C-1 by 10%; for C-2 through C-7 by 20%; for C-3 by 30% with no downward adjustment for C-9. The adjustment was done on the basis of analysis of labor breakdown distribution shown in the source. Capital inputs requirements were estimated from the total volume of work required (e.g. mixing 100 m^3 of concrete) and from productivity data of specific machinery as shown in appendix.

Section VIII

Doors, Windows and Skylights

Construction components analyzed in this section are shown in Table 1

Table 1

Designation	Description
Door-1	Combined metal-wooden doors of industrial type buildings. (With weather stripping)
Door-2	Combined metal-wooden doors of a warehouse type
Window-1	Double frames (wooden)
Window-2	Single frames (wooden)
Window-3	Metal frames
Skylight-1	Trapezoidal

Unit of measurement for windows and door - 100 m^2 of aperture; for skylights - 100 m^2 of horizontal plane area.

Table 2 shows material, labor and flow input requirement of these components.

	Unit	Door 1	Door 2	Window 1	Window 2	Window 3	Skylight 1
Alabaster	tons	-	-	0.23	0.16	-	-
Bolts, nuts, washers	kg	-	-	-	-	-	40
Felting	m^2	115	210	100	72	-	-
Forgings	kg	150	150	80	80	80	25
Fibrelite	units	-	-	-	-	-	14
Glass	m^2	-	-	150	75	180	52
Lumber (sawed)	m^3	-	-	-	-	-	0.95
Nails	kg	1.6	4	6	4	-	87
Paint, oil	kg	70.0	57.0	45	31.5	14.2	24
Paint, others	kg	60.9	51.2	36.9	26.4	32.3	14
Panel (and/or frames)(or m^2)	m^2	85	84	170	85	4	64
Putty	kg	-	-	200	100	350	54
Ruberoid	m^2	-	-	-	-	-	19
Sheet iron	tons	0.22	0.55	-	-	-	0.147
Tar	tons	-	-	0.05	0.03	-	-
Whiting	kg	69	27	54	38	-	26
Labor	man/hr	712	680	704	456	424	544
Electrical power	KWH	7	7	10	5	112	6

Source: I.A. Petrov, pp 43-45, 35, 164-169

Section IX

Other structural elements of industrial buildings

This section summarizes input requirements for all major construction components not covered elsewhere in the study. The treatment of specific components in this section is somewhat different from other sections. The Soviet consolidated data used distinguishes a great number of different components of this type (e.g. 37 types of roofs as compared with only 6 types of reinforced concrete and metal skeleton frames). Thus, some averaging as well as exclusion of component types no longer used in construction was required in order to keep the study to managable proportions and to facilitate further analysis. Table 1 shows the main characteristics of components chosen.

Table 1

Other structural elements of industrial buildings

Designation	Unit of measurement	Description
Floor-1	100 m^2	Asphalt ground floors of industrial buildings on a concrete base.
Floor-2	100 m^2	Asphalt floors, other than ground floor
Floor-3	100 m^2	Cement ground floors on a concrete base
Floor-4	100 m^2	Cement ground floors on a rubble base
Floor-5	100 m^2	Wooden floor on a sand base
Partition-1	100 m^2	An average of five different types of wooden partitions
Partition-2	100 m^2	An average of two brick partitions (one of 1/4 brick thickness: the second 1/2 brick thickness without metal reinforcing)
Partition-3	100 m^2	Reinforced concrete (heavy gravel type)
Partition-4	100 m^2	Light concrete (slag) type partition without metal reinforcing.
Stairways-1	100 m^2 of flights (horizontally projected)	Reinforced concrete steps mounted on steel bridgeboards
Stairways-2	100 m^2 of flights	Reinforced concrete steps mounted on reinforced concrete bridgeboards

Table 1 continued

Finishing Interior-1	100 m^2 of area	Plaster of walls, ceilings and inclines with painting
Finishing Interior-2	100 m^2 of area	Painting without plaster.
Finishing Exterior-1	100 m^2 of outside walls	Plaster of the base and inclines. Mounting of drain pipes and placing tin on window sills.
Finishing Exterior-2	100 m^2 of outside walls	Complete plaster. Mounting of drain pipes and placing tin on window sills.
Roofing-1	100 m^2 of building area	Tin covered timber roofs
Roofing-2	100 m^2 of building area	Ruberoid covered timber roofs
Roofing-3	100 m^2 of building area	Ruberoid covered reinforced concrete slabs with metal beams. Slag insulated.

Table 2 shows material, labor and flow input requirements per unit of measurement of specified structural elements.

It will be noted that capital input requirements are omitted from this section. Soviet sources on consolidated data specify capital input requirements in value terms (mainly depreciation) per unit of component thus making the translation into physical units of specified capital equipment extremely difficult if not impossible. In previous sections of this study where processes were much more capital intensive, individual processes were analyzed and specific units of capital equipment "assigned" to them. Analysis of the breakdown of labor into professions shows that components covered in this section require almost no "machinist" and very small number of concrete workers. This indicates a rather limited use of hoisting equipment and concrete mixing equipment. The comparison of ruble cost of capital equipment used (depreciation) also shows that elements of buildings analyzed in this section do not extensively utilize machinery (1). Labor input requirements given in Table 2 were not adjusted as elsewhere in the study.

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(1) As an example we can compare the depreciation costs of two different groups of components as shown in Petrov, p. 98. Analysis of a three-story high building shows that the ruble cost of machinery used in foundation, masonry and concrete ceiling work is about 170 rubles as compared with 32 rubles of machine costs for all roofing, floors and partitions of the building.

TABLE 2 MATERIAL, LABOR, AND FLOW INPUTS OF SPECIFIED ELEMENTS OF BUILDINGS

													FINISHING		PAINTING				
INPUTS	UNITS	FLOOR 1	FLOOR 2	FLOOR 3	FLOOR 4	FLOOR 5	PARTITION 1	PARTITION 2	PARTITION 3	PARTITION 4	STAIRWAYS 1	STAIRWAYS 2	INTERIOR 1	INTERIOR 2	EXTERIOR 1	EXTERIOR 2	ROOFING 1	ROOFING 2	ROOFING 3
Alabaster	M 3	-	-	-	-	-	-	-	-	-	-	-	3.3	-	-	-	-	-	-
Asphalt (Bitumen)	TONS	0.4	0.4	-	-	1.4	-	-	-	-	-	-	-	-	-	-	-	1.3	1.3
Asphaltic Putty	TONS	2.9	2.9	-	-	0.16	-	-	-	-	-	-	-	-	-	-	-	-	-
Blocks, Concrete	M 3	-	-	-	-	-	-	-	-	-	59.0	-	-	-	-	-	-	-	-
Blocks, Steps, Concrete	M 2	-	-	-	-	-	-	-	-	-	200.0	200.0	-	-	-	-	-	-	-
Bolts	K g	-	-	-	-	-	-	-	-	-	5.0	5.0	-	-	-	-	10	52.0	-
Brick, Common	1,000 un.	-	-	-	-	-	-	4.1	-	-	-	-	-	-	-	-	-	-	-
Cement, Portland	TONS	2.8	-	4.5	1.7	-	-	0.28	3.1	3.4	1.88	3.67	-	-	-	-	-	-	2.55
Concrete	M 3	(12.0)	-	(12.0)	-	-	-	-	(9.2)	(17.3)	-	(10.2)	-	-	-	-	-	-	(5.8)
Forgings	TONS	-	-	-	-	-	-	-	-	25.0	14.0	3.0	10.0	10.0	17.0	24.0	130.0	43.0	-
Gravel	M 3	1.1	1.1	-	-	-	-	-	10.3	-	-	9.9	-	-	-	-	-	1.3	6.2
Lime (slaked)	TONS	-	-	-	1.2	-	-	0.15	-	-	1.45	1.45	0.54	0.01	0.24	0.63	-	-	-
Lumber-round	M 3	-	-	-	-	-	-	-	-	-	-	4.15	3.7	3.7	-	-	4.0	3.3	1.5
Lumber-sawed	M 3	-	-	-	-	3.15	5.1	-	2.2	2.2	0.35	5.9	1.3	1.3	0.4	1.3	3.7	7.0	3.1
Mortar-Lime	M 3	-	-	-	(5.4)	-	-	(1.9)	-	-	(6.9)	(6.9)	(2.5)	-	(0.9)	(2.9)	-	-	-
Nails	K g	-	-	-	-	-	13.0	-	29.0	26.0	-	86.0	23.0	18.0	4.0	11.0	27.0	33.0	1.0
Paint, Iron Oxide	K g	-	-	-	-	-	-	-	-	-	-		-		3.9	3.9	25.0	-	18.0
Paint, Oil	K g	-	-	-	-	-	-	-	-	-	4.8	4.8	-	-	2.2	2.2	17.0	1.2	4.3
Paint, Other	K g	-	-	-	-	-	-	-	-	-	4.1	4.1	2.4	2.4	0.7	0.7	1.1	0.1	-
Pergamyn	M 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	137.0	137.0
Plywood	M 2	-	-	-	-	-	42	-	-	-	-	-	-	-	-	-	-	-	-
Rubble (Brick)	M 3	17.0	-	17.0	19.0	-	-	-	-	-	1.65	1.65	-	-	-	-	-	-	-
Ruberoid	M 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	137.0	137.0
Sand	M 3	6.0	0.7	7.8	8.2	14.0	-	2.9	6.6	0.2	11.5	14.2	2.8	-	1.1	3.3	-	-	6.1
Sheet Iron	TONS	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09	0.09	0.69	0.07	0.02
Slag	M 3	-	-	-	-	-	1.6	-	-	26.0	-	-	-	-	-	-	-	-	16.0
Steel, Reinforcing, Rolled	TONS	-	-	-	-	-	-	0.2	0.33	-	-	0.3	-	-	-	-	-	-	-
Steel, Reinforcing, Profile	TONS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7
Steel, Structural	TONS	-	-	-	-	-	-	-	-	-	3.1	2.97	-	-	-	-	-	-	2.2
TAR	TONS																		
Whiting	M 3	-	-	-	-	-	-	-	-	-	41.8	41.8	30.0	30.0	-	-	0.8	0.8	-
Wire	K g	-	-	-	-	-	-	-	27.0	8.0	-	-	-	-	2.0	2.0	1.0	-	-
FLOW INPUTS																			
1. Water	M 3	3.0	-	5.0	6.0	1.0	-	2.5	32.0	13.0	5.0	20.0	2.0	-	1.0	3.0	-	-	1.5
2. Electrical Power	KWH	12.0	7.0	8.0	8.0	-	1.4	6.5	27.0	29.0	10.0	28.0	5.0	5.0	2.0	5.0	6.0	17.0	74.0
LABOR	MAN-hrs	328	144	360	376	368	288	188	248	224	1,136	1,936	168	27	184	352	288	325	480

SOURCE - I. A. Petrov pp 27 - 46, pp 161 - 172

Appendix 1

Capital Equipment Used in Construction

The appendix shows the most important groups of machinery used in construction in the Soviet Union. Productivity and output data as well as fuel and/or electrical power consumption is factual data. The theoretical ("pasportnaia") productivity which is usually much higher is now shown. It should be noted that the total requirement in machinery cannot be estimated directly on the basis of hourly productivity. Time-off needed for transportation to and from the construction site, time needed for assembling, rigging and dismounting of machinery (when applicable) as well as time-off for maintenance and repair should be taken into consideration. In addition machinery in construction will often be idling. Following table can serve as an illustration:

Table A-1

Machine-time utilization by a large construction organization for specified types of machines. (Percent breakdown)

Type	Time in use	Time idling	Time for repairs(1)	Time for moving from and to jobs
Power shovels, 0.5 m^3 capacity	59.2	22.3	17.8	0.7
Power shovels, 0.25 m3 capacity	66.1	14.6	18.3	1.0
Power shovels-cranes	69.9	11.2	17.2	1.7
Cranes mounted on trucks	62.0	17.6	20.2	0.2
Turret cranes	62.0	14.4	5.6	18.0

Source: P. Pavlov, p. 69

Note: 1) Time-off for repair and waiting for repair

The normative requirements which presumably take into the account necessary time-off and idling for some types of construction machinery are shown in Table A-2.

Table A-2

Type	Norms of output per year
Cranes self-propelled, turret, rail or crawler	For hoisting, assembly work and loading and unloading - 2,400 hours
Power shovels, capacity 0.5 m^3 and up	110,000 m^3 of earth per 1 m^3 of bucket capacity
Trenching machines	750 m^3 of earth per 1 liter of bucket capacity
Tractor scrapers	5,000 m^3 of earth per 1 m^3 of bucket capacity
Bulldozers	2,400 hours

Source: A. Vainson, p.6

This Appendix shows following classes of construction machinery:

1. Trucks - Table A-3
2. Earthwork and excavation - Tables A-4 through A-8
3. Masonry and concrete work - Tables A-9 through A-12
4. Hoisting equipment - Tables A-13 through A-16

Table A-3

Trucks

		GAZ-51	ZIL-150	GAZ-93	ZIL-585	MAZ-205	IAZ-210
Type	-	box	box	dumper	dumper	dumper	dumper
Carrying capacity	tons	2.5	4	2.25	3.5	6	10
Type of Engine	-	gasoline	gasoline	gasoline	gasoline	diesel	diesel
Number of Cylinders	-	4	6	4	6	4	6
Max. horsepower	HP	70	90	70	90	110	165
Max. speed fully loaded	km/hr	70	65	70	65	60	45
Number of axles	-	2	2	2	2	2	3
Weight	tons	2.7	3.9	4.14	5.25	6	9.76
Fuel consumption per 100 km	l	26.5	38	28	40	40	80
Average productivity per hour	tons	2.1	3.6	2.8	4.0	5.0	11.2

Sources and Notes:

Sources, Onufriev, pp 514, 523-525, Merkushev, pp 182-203

Average productivity per hour is calculated for average roads, with the distance travelled both ways between 4 and 7 km, and total time spent loading and unloading between 0.4 and 0.75 of one hour for box-type trucks and between 0.3 and 0.4 of one hour for dumpers.

Table A-4

Power Shovels

	Unit	E-258 E-257	E-505A D-051	E-1004 E-1252	E-2002
Capacity of bucket (direct)	m^3	0.25–0.35	0.5–0.75	1.0–1.5	2.25–3
Engine-type and power rating	HP	D-37	D-80	D-120	D-250
Weight	tons	10.5	20.5	40	78
Size - Length	m	4	4.7	5.3	6.7
" Width	m	2.5	2.9	3.2	4
" Height	m	3	3.5	3.7	6.3
Max. depth of excavation	m	.35	1.5	2.0	2.2
Max. height of excavation	m	5.00	6.6	8.0	11.5
Reversed bucket-capacity	m^3	0.25	0.5	-	-
Max. depth (reversed bucket)	m	4.0	5.6	-	-
Max. height of unloading	m	2.3	2.2	-	-
Fuel expenditure per 1 hr of work	kg	5.5	8–9.5	13.5	20.0
Annual output 1)	$1000 m^3$	30–40	60–80	120–170	226–320
Output per hour 1)	m^3	15–25	30–45	60–90	70–150
Operated by (per 8 hr of work) 2)	man-days	2–3	3–4	4	7–9

Sources:
Characteristics: Onufriev, pp. 441-443; Vainson, pp.390–424
Fuel expenditure, Onufriev, pp. 482–483
Productivity: Nebol'sin, pp 88–90

Notes: 1) Average for different types of earth and working conditions shown. About 6% of the weight of diesel fuel should be added for lubricants
2) Man-day is 8 hours

Table A-5

Draglines

	Units	E-258 E-257	E-505 E-651	E-1004A E-1252
Capacity of the bucket	m^3	0.25	0.5	1.0
Length of the boom	m	10.5	10-13	13-16
Max. depth of digging	m	3.9	6-9	8
Max. height of unloading	m	4-6	5-8	5.7
Engine-type and power rating	HP	D-37	D-80	D-120
Weight	tons	10.5	20.5	40
Size - Length	m	4	4.7	5.3
Width	m	2.5	2.9	3.2
Height	m	3	3.5	3.7
Fuel expenditure per 1 hr. of work	kg	5.5	8-9.5	13.5
Same equipped with clamshell-capacity	m^3	0.35-0.5	0.5	1.5
Max. depth	m	4.64	6.0	7.2

Sources:

Characteristics: Onufriev, pp 441-443; Vainson, pp 390-424

Fuel Expenditure: Onufriev, pp 482-483

Table A-6

Trenching machines (Ladder-Type)

	Unit	ET-121	ET-251	ETU-353
Depth of trench	m	1.2	2.5	3.5
Width of trench	m	0.5	0.8	0.8
Capacity of bucket	l	12	45	45
Number of buckets	-	19	12	-
Engine-type	-	diesel	diesel	diesel
-power rating	HP	54	54	54
Size- Length	m	4.7	8.3	9.8
" Width	m	2.27	3.8	4.6
" Height	m	3.9	3.4	3.5
Weight	tons	8.1	10.7	12.4
Fuel consumption per hour	kg	8	8	8
Output per year	$1000m^3$	9	34	34

Sources: Onufriev, p.444; Vainson, p.6, pp 457-472, Zimin, pp. 304-305

Table A-7

Bulldozers

	Unit	D-216	D-159	D-259	D-157
Blade - length	cm	200	228	415	302
Blade - height	cm	60	80	100	110
Maximum depth of cut	cm	15	15	180	180
Mounted on tractor-type		KD-35	DT-54	S-80	S-80
Engine	HP	D-37	D-61	D-93	D-93
Size-Length	m	3.7	4.3	5.5	5.1
" -Width	m	2	2.3	4.2	3.0
" -Height	m	2	2	3	2.9
Weight, inc. Tractor	tons	4.8	6.5	14	14.5
Fuel consumption per 1 hr. 1)	kg	5	8	10	10
Output-annual 2)	$1000m^3$	100	100	100	100
Output-per hour	m^3	100	100	100	100

Sources and notes

Characteristics: Onufriev, p 446, Zimin p.307

1) Fuel consumption: Onufriev, p 483

2) Output and productivity: Nebol'sin, p 92

Output and productivity in filling in trenches or in similar work

Table A-8

Scrapers (all tractor pulled)

	Units	D-217	D-183 D-230	D-222	D-213	D-188
Capacity of bucket	m^3	1.5-1.7	2.3-2.5	8-10	10-12	15-18
Cutting-width	m	1.5	1.6-1.8	2.6	2.8	3.1
" -max. depth	cm	12	13-15	30	30	30
" -angle	degrees	30-35	30-35	35	30	35
Track-front wheels	m	1.93	0.9	1.25	1.65	2.2
-rear wheels	m	-	1.4	1.78	1.95	1.95
Size -length	m	3.9	5	8.4	9.8	11
" -width	m	2.2	2	3	3.3	3.5
" -height	m	1.6	2.5	3.1	3.2	3.1
Weight	tons	1.2	1.8-2.4	6.6	8.5	15.75
Used with tractor	type	KD-35	DT-54	S-80	S-80	S-140
Output per annum 1)	$1000m^3$	15	15	30	50	n.a.
Output per hour 1)	m^3	45	40	45	70	n.a.
Operated by (per 8 hr. of work)	man-days	2	2	2	2	2
Fuel consumption per hour	kg	5.5	8	10.5	10.5	n.a.

Sources and Notes

Characteristics: Onufriev, p 445, Zimin, p. 306

Fuel consumption: Onufriev, p. 483

Productivity: Nebol'sin, pp.90-91

Note: 1) Output per year and per hour given for D-217 and D-183/D-230 moving earth at a distance of 50m, rest up to 100m.

Table A-9

Concrete Mixers

	Units	C-227	C-99	C-336	C-302	C-306	C-224
Type	-	movable	movable	movable	stationary	auto	auto
Capacity	l	100	250	425	1200	1600	2100
Rotations of the drum	RPM	24.5	16	18	17	9	9
Size-Length	m	2.4	2.4	2.5	3.7	6.4	7.5
" -Width	m	1.1	1.9	2.4	2.7	2.3	2.6
" -Height	m	1.6	3.0	2.2	2.5	2.9	3.2
Weight	tons	.65	2.0	2.15	4.3	2.2	2.7
Motor-power rating	KH	3.2	5	2.8	14	-	-
-RPM	RPM	2,200	1,000	1420	980	-	-
Productivity per hour	m^3	2.2	6	8	20	-	-
For automobile mixers only							
Mounted on		-	-	-	-	Zis-150	IAZ-200
Engine		-	-	-	-	truck's	30HP
Fuel expenditure per hr.	kg	-	-	-	-	5	5
Capacity of drum for transportation	l	-	-	-	-	2000	2400

Sources: Onufriev p.453; Zimin pp.332-333

Table A-10

Riddles for gravel, rubble or sand

	Unit	S-96	SM-60	SM-61	SM-13
Productivity per hour	m^3	13-16	30-40	30-40	30-40
Number of screens	-	3	2	3	2
Size of screens	m	2x.75	3x1.2	3x1.2	2.4x.9
Movements per minute	-	1200	1100	975	740
Size-length		2.3	3.2	3.2	3.1
" width		1.4	2.1	2.2	1.9
" height		1.4	1.7	1.9	1.2
Weight - without motor	kg	900	2080	2791	1715
Electrical motor-power rating	kw	4.5	5.8	7.8	5.2
"	RPM	1,440	1,350	1,350	1,000

Source: Onufriev, p. 449

Table A-11

Crushers

	Unit	Small	Medium	Large
Diameter of crusher	m	.9	1.2	1.65
Width of loader	m	.12	.17	.25
Size-length	m	1.8	2.6	3.4
" width	m	1.6	2.3	2.8
" height	m	2.4	3.1	3.1
Motor-power rating	kw	40-55	70-80	135-150
" - RPM	RPM	735	735	735

Source: Onufriev, p. 452

Table A-12

Mortar mixers

	Unit	S-50	C-220A	C-219	C-209
Capacity of the drum	l	80	150	325	750
Production per hour	m^3	1.5	3	5.2	19.5
Rotation of the drum	RPM	26	30.2	25.8	21.6
Size-Length	m	2.1	2.8	2.4	2.9
" Width	m	.8	1.5	2.3	2.2
" Height	m	1.4	1.8	1.9	1.6
Weight	tons	.47	.99	2.18	3.0
Motor-power rating	kw	2	2.8	4.3	14
" - RPM	RPM	1000	1420	1445	1000

Sources: Onufriev, pp. 453-455; Zimin p. 335

Table A-13

Tower Cranes - Self-propelled

	Unit	BKSM -1	BKSM -2	T-128	BK-5	BK-404
Hoisting capacity (boom-out)	tons	0.5	1.0	1.5	3.0	18.0
same (boom-in)	tons	1.0	2.0	3.0	5.0	40.0
Boom-out	m	10.0	17.5	20.0	22.7	30.0
Boom-in	m	5.0	8.8	10.0	9.0	8.0
Speed-of hoisting	m/min	20.0	30.0	30.0	30.0	7.0
boom swing	RPM	0.8	0.6	0.6	0.6	0.17
of crane on rails	m/min	20.0	20.0	30.0	22.0	-
Motors - hoisting	kw	5.0	7.5	16.0	30.0	44.0
- boom swing	kw	1.0	2.5	2.2	5.0	5.0
- crane moving	kw	2.5	5.0	11.0	22.0	-
- total	kw	8.5	15.0	29.2	70.5	71.0
Track - width	m	2.5	3.0	3.8	6.0	9.5
Weight	tons	8.8	22.5	51.5	111.5	236.9
Electrical power consumption-hr	KWH	1.6	3.1	5.7	7.8	12.4
Output per hour (number of hoists;)						
for height shown	m	7-10	7-10	16	10-50	30-70
1) Hoisting of brick & concrete		18-25	14-18	18-20	12-18	-
2) Assembly of metal or concrete elements		-	11	11	-	-
3) Hoisting of columns or large panels		-	-	-	3.4	-
4) Large sections 10 to 40 tons		-	-	-	-	0.2-0.4
Output tons/hr						
1) Assembly (Metal or concrete)	ton/hr	1.9	3.1	3.3	n.a.	n.a.
2) Loading-unloading-hoisting	ton/hr	5.6	9.3	10.0	n.a.	n.a.

Sources: B. V. Antrushin, pp. 188-288; Onufriev, p. 438; Zimin, pp. 315-316
Nebol'sin, pp. 103-107

Table A-14

Cranes - Stationary

	Unit	T-73	T-95	MK 1002	T-72	UBK 5-49	UBK 1.5-49	UBK 15-49
Hoisting capacity, (boom out)	tons	5	15	4	0.8	5.0	1.5	15.0
same (boom in)	tons	5	15	10	0.8	5.0	1.5	15.0
Boom, length	m	21.4	38.5	-	-	-	-	-
Boom-out		22.0	37.0	17.1	25	27.5	22.0	22.0
Boom-in		3.5	3.0	4.5	4.4	2.2	2.0	4.5
Speed of hoisting	m/min	24.0	15.0	35	39	36	45	20
Speed of crane rotation	RPM	0.2	0.5	-	1	0.2	0.6	0.12
Motors-total power rating	KW	40	58	24.2	19.0	63	28.7	123.0
Weight	tons	15.2	56	34.1	13.0	29.2	25.8	90.0
Electrical power consumption per hour	KWH	8	8	2.8	4.0	5.5	3.2	11.0
Output (number of hoists) per hour height 10 to 35 meters	-							
1) Assembly of metal or concrete elements		2.6	2.0	2.0	12	2	12	2
2) Hoisting of concrete mixture		-	-	-	25	-	22	-
3) Heavy panels or columns		-	-	-	-	2-3	-	2
Output-tons/hr used in assembly work	ton/hr	7.4	14	n.a.	n.a.	n.a.	3.8	n.a.

Sources: B.D. Antrushin, pp. 50-107, Onufriev, p. 438; Nebol'sin, pp. 103-107

Notes: T-73, T-95 Guy derricks with jibs

MK-1002 Mast crane (derrick)

UBK's Tower cranes (self lifting)

Table A-15

Other Hoisting and Lifting Equipment

	Units	T-37	T-41	T-80	T-144	T-164
Hoisting capacity	tons	.3	.5	-	-	-
Max. height	m	16	38	3.7	5.4	3.7
Speed of hoisting	m/sec	0.6	0.7	0.8	1.6	1.0
Size of the platform	m	1.0x1.6	1.0x2.0	-	-	-
Width of the belt	m	-	-	.4	.5	.4
Weight	tons	2.2	2.5	.35	1.0	.44
Motor-power rating	KW	4.5	7.0	1.5	2.8	1.7

Sources: Onufriev, pp. 439-440; Vainson, p. 252-258

Notes: T-37 and T-41: Mast lifts

T-80, T-144, T-164: Belt transporters

Table A-16

Automobile Cranes

	Unit	K-32	K-51	K-52	K-104
Hoisting capacity	tons	0.4-1.0	0.75-2.0	0.75-2.0	1.0-4
Boom	m	2.5-5.5	3.8-6.5	3.8-7.0	4-10
Boom-length	m	6.2	7.35	7.5	10
Speed of hoisting	m/min	14.6	12.8	12.0	4-9
Automobile-type	-	ZIL-150	MAZ-200	MAZ-200	IAZ-210
Power rating	HP	90	110	110	125
Weight	tons	7.5	12.8	13	22.8
Fuel consumption per hour	1-kb	4.5(1)	6(kg)	6(kg)	8(kg)
Output-assembly work	tons/hr	10.1	21.2	n.a.	n.a.
- loading-unloading-hoisting	tons/hr	30.0	60.0	n.a.	n.a.

Source: Onifriev, p. 436, Nebol'sin, p. 106

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