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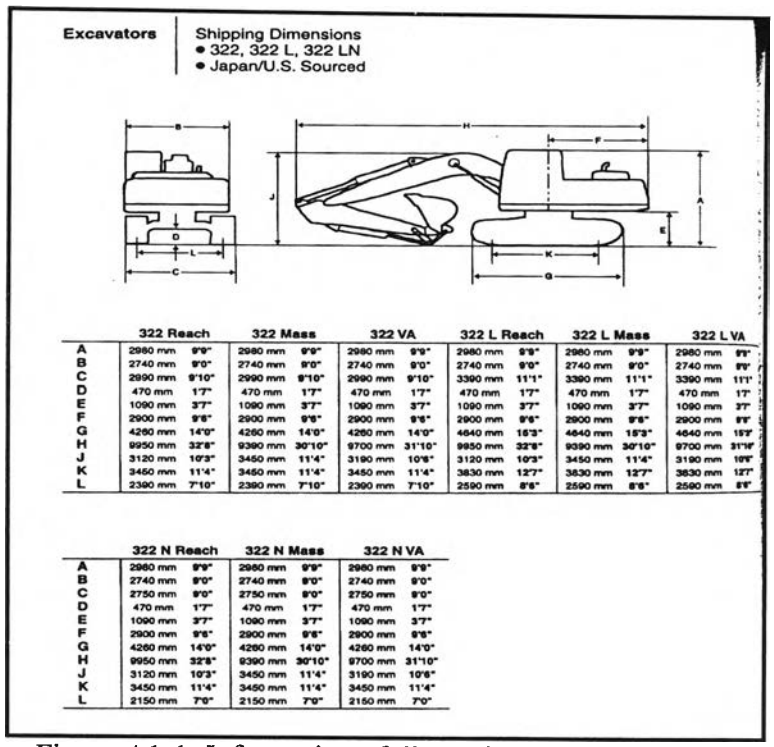
APPENDICES

Appendix 1

Examples of Information of Construction Equipment



Excavators | Shipping Dimensions
- 322, 322 L, 322 LN
- Japan/U.S. Sourced

	322 Reach	322 Mass	322 VA	322 L Reach	322 L Mass	322 L VA
A	2980 mm 9'9"	2980 mm 9'9"	2980 mm 9'9"	2980 mm 9'9"	2980 mm 9'9"	2980 mm 9'9"
B	2740 mm 9'0"	2740 mm 9'0"	2740 mm 9'0"	2740 mm 9'0"	2740 mm 9'0"	2740 mm 9'0"
C	2990 mm 9'10"	2990 mm 9'10"	2990 mm 9'10"	3390 mm 11'1"	3390 mm 11'1"	3390 mm 11'1"
D	470 mm 1'7"	470 mm 1'7"	470 mm 1'7"	470 mm 1'7"	470 mm 1'7"	470 mm 1'7"
E	1090 mm 3'7"	1090 mm 3'7"	1090 mm 3'7"	1090 mm 3'7"	1090 mm 3'7"	1090 mm 3'7"
F	2900 mm 9'6"	2900 mm 9'6"	2900 mm 9'6"	2900 mm 9'6"	2900 mm 9'6"	2900 mm 9'6"
G	4260 mm 14'0"	4260 mm 14'0"	4260 mm 14'0"	4640 mm 15'3"	4640 mm 15'3"	4640 mm 15'3"
H	9950 mm 32'8"	9390 mm 30'10"	9700 mm 31'10"	9950 mm 32'8"	9390 mm 30'10"	9700 mm 31'10"
J	3120 mm 10'3"	3450 mm 11'4"	3190 mm 10'6"	3120 mm 10'3"	3450 mm 11'4"	3190 mm 10'6"
K	3450 mm 11'4"	3450 mm 11'4"	3450 mm 11'4"	3830 mm 12'7"	3830 mm 12'7"	3830 mm 12'7"
L	2390 mm 7'10"	2390 mm 7'10"	2390 mm 7'10"	2590 mm 8'6"	2590 mm 8'6"	2590 mm 8'6"

	322 N Reach	322 N Mass	322 N VA
A	2980 mm 9'9"	2980 mm 9'9"	2980 mm 9'9"
B	2740 mm 9'0"	2740 mm 9'0"	2740 mm 9'0"
C	2750 mm 9'0"	2750 mm 9'0"	2750 mm 9'0"
D	470 mm 1'7"	470 mm 1'7"	470 mm 1'7"
E	1090 mm 3'7"	1090 mm 3'7"	1090 mm 3'7"
F	2900 mm 9'6"	2900 mm 9'6"	2900 mm 9'6"
G	4260 mm 14'0"	4260 mm 14'0"	4260 mm 14'0"
H	9950 mm 32'8"	9390 mm 30'10"	9700 mm 31'10"
J	3120 mm 10'3"	3450 mm 11'4"	3190 mm 10'6"
K	3450 mm 11'4"	3450 mm 11'4"	3450 mm 11'4"
L	2150 mm 7'0"	2150 mm 7'0"	2150 mm 7'0"

Figure A1-1: Information of dimensions of an excavator
(*Caterpillar Performance Handbook, Edition 26*)

Excavators | Specifications

MODEL	322 L	322 L	322 N	322 N
Sourcing	Japan	Belgium	Japan	Belgium
Flywheel Power	114 kW 153 hp	114 kW 153 hp	114 kW 153 hp	114 kW 153 hp
Operating Weight*	23 950 kg 52,800 lb	24 320 kg 53,600 lb	22 600 kg 49,844 lb	23 200 kg 51,220 lb
Bucket Capacity Range (heaped)	0.9-1.5 m³ 1.18-1.96 yd³	0.83-1.9 m³ 0.82-2.5 yd³	0.9-1.4 m³ 1.18-1.83 yd³	0.83-1.9 m³ 0.82-2.5 yd³
Engine Model	3116T	3116T	3116T	3116T
Rated Engine RPM	1950	1950	1950	1950
No. of Cylinders	6	6	6	6
Bore	105 mm 4.1"	105 mm 4.1"	105 mm 4.1"	105 mm 4.1"
Stroke	127 mm 5.0"	127 mm 5"	127 mm 5.0"	127 mm 5.0"
Displacement	6.6 L 403 in³	6.6 L 403 in³	6.6 L 403 in³	6.6 L 403 in³
Max. Implement Hydraulic Pump at Rated RPM	2 × 205 L/min 2 × 54 gpm	2 × 205 L/min 2 × 54.2 gpm	2 × 205 L/min 2 × 54 gpm	2 × 205 L/min 2 × 54.2 gpm
Relief Valve Settings				
Implement Circuits	31 400 kPa 4554 psi	31 390 kPa 4550 psi	31 400 kPa 4550 psi	31 390 kPa 4550 psi
Travel Circuits	34 300 kPa 4980 psi	34 330 kPa 4980 psi	34 300 kPa 4980 psi	34 330 kPa 4980 psi
Swing Circuits	25 500 kPa 3700 psi	25 500 kPa 3980 psi	25 500 kPa 3700 psi	25 500 kPa 3980 psi
Pilot Circuits	3400 kPa 500 psi	3430 kPa 500 psi	3400 kPa 508 psi	3430 kPa 500 psi
	Two Speed Travel	Two Speed Travel	Two Speed Travel	Two Speed Travel
Maximum Drawbar Pull	Lo: 194 kN 43,650 lb Hi: 108 kN 24,500 lb	Lo: 194 kN 43,446 lb Hi: 108 kN 24,039 lb	Lo: 194 kN 43,650 lb Hi: 108 kN 24,500 lb	Lo: 194 kN 43,446 lb Hi: 108 kN 24,038 lb
Maximum Travel Speed at Rated RPM	Lo: 3.4 km/h 2.1 mph Hi: 5.5 km/h 3.4 mph	Lo: 3.4 km/h 2.1 mph Hi: 5.5 km/h 3.4 mph	Lo: 3.4 km/h 2.1 mph Hi: 5.5 km/h 3.4 mph	Lo: 3.4 km/h 2.1 mph Hi: 5.5 km/h 3.4 mph
Width of Standard Track Shoe	600 mm 24"	600 mm 24"	600 mm 24"	600 mm 24"
Overall Track Length	4640 mm 15'3"	4640 mm 15'2.7"	4260 mm 14'0"	4260 mm 13'11.7"
Ground Contact Area with Std. Shoe and Std. Undercarriage	6.58 m² 10,200 in²	6.54 m² 10,200 in²	4.48 m² 6940 in²	4.48 m² 6940 in²
Track Gauge	2590 mm 8'6"	2580 mm 8'6"	2150 mm 7'1"	2145 mm 7'0"
Fuel Tank Refill Capacity	340 L 90 U.S. gal	370 L 98 U.S. gal	340 L 90 U.S. gal	370 L 98 U.S. gal

*Operating weight includes coolant, lubricants, full fuel tank, standard shoes, bucket and operator 75 kg (165 lb)

Note: Certain models may not be available in all Sales Areas.
Specifications may also vary by Sales Area.
Contact your Caterpillar Dealer Office for details.

Figure A1-2: Information of properties of excavators
(*Caterpillar Performance Handbook, Edition 26*)

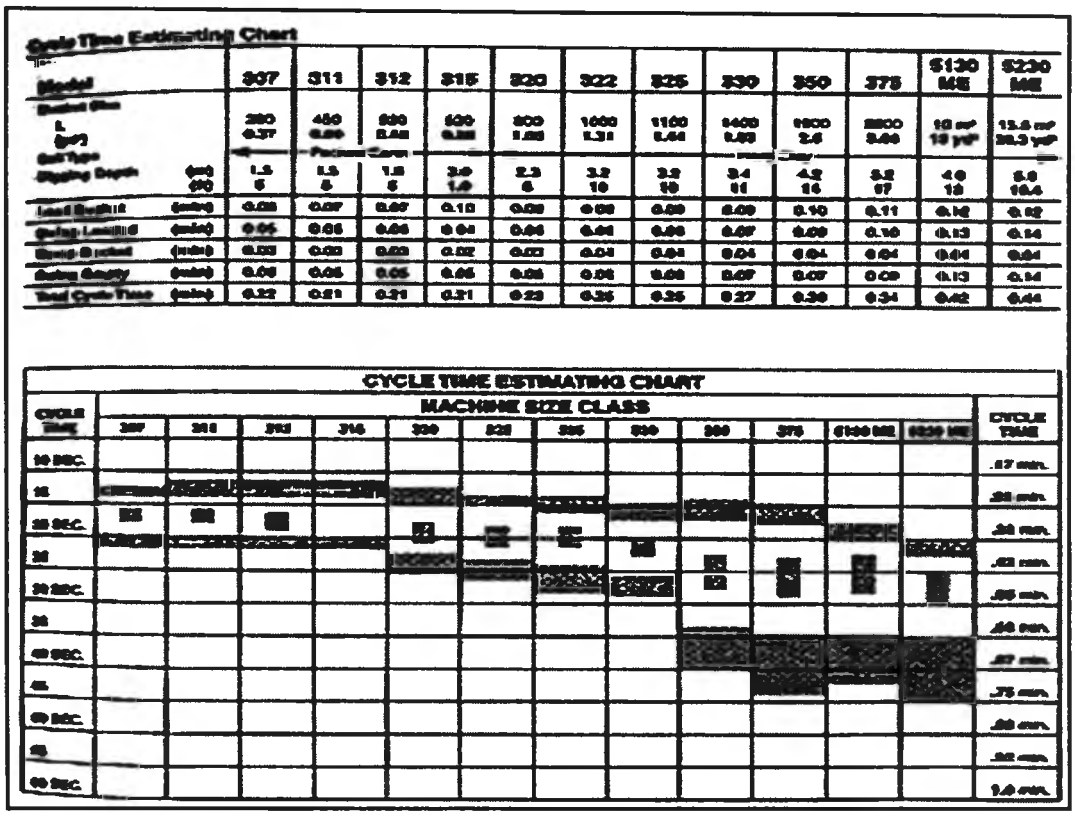


Figure A1-3: Cycle time estimating chart of excavators
(*Caterpillar Performance Handbook, Edition 26*)

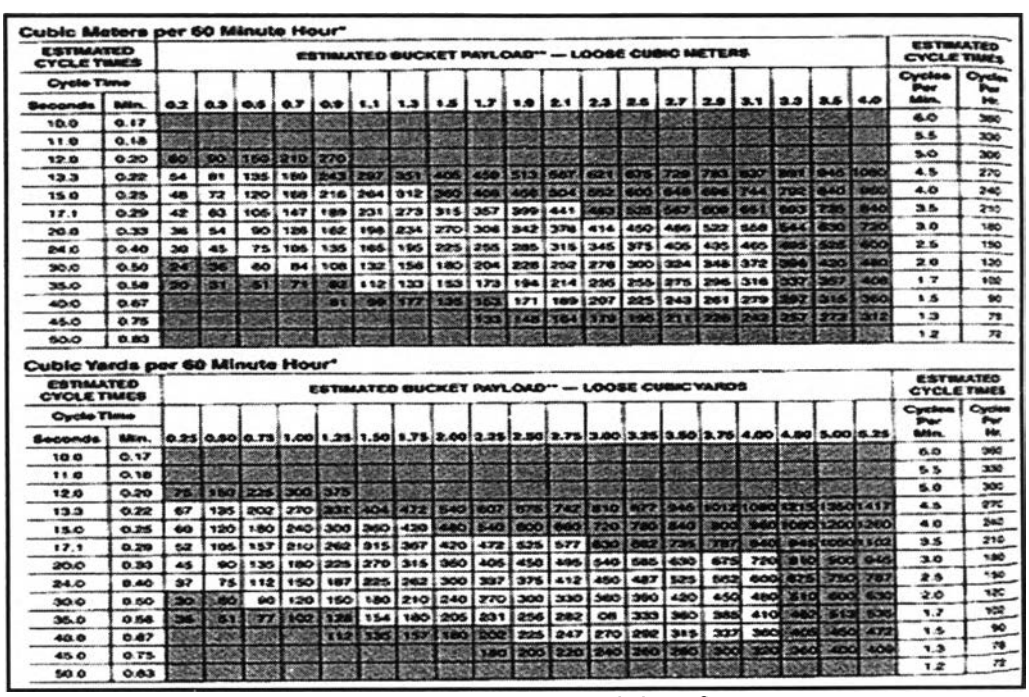


Figure A1-4: Information of productivity of an excavator
(*Caterpillar Performance Handbook, Edition 26*)

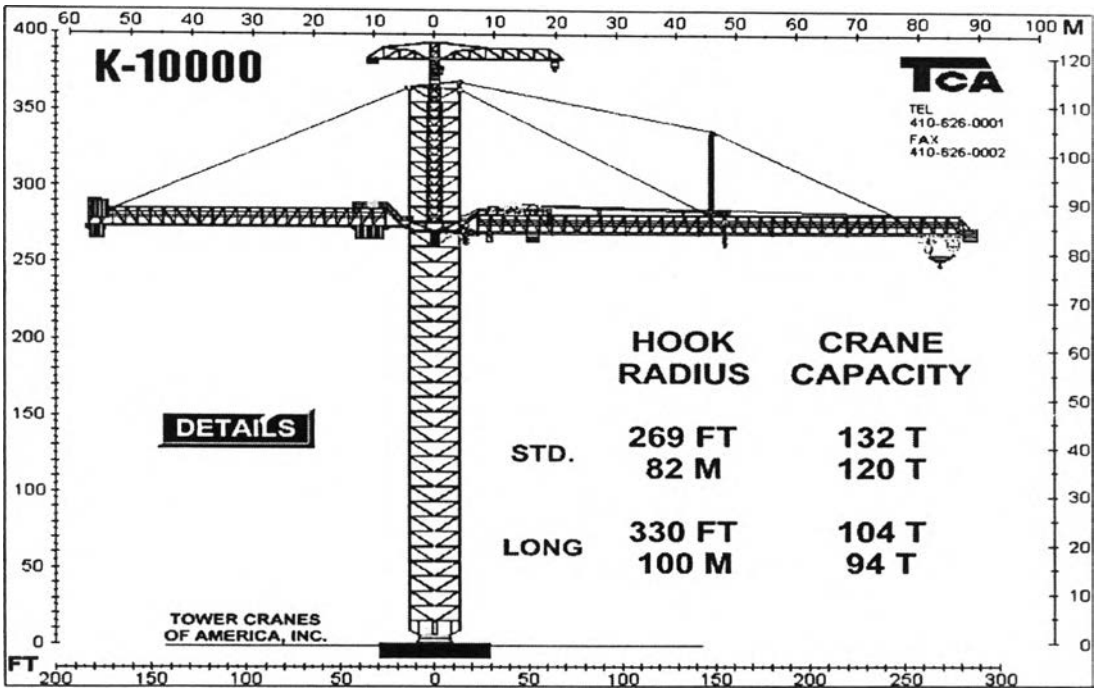


Figure A1-5: Information of dimensions of a tower crane (*www.crane.com*)

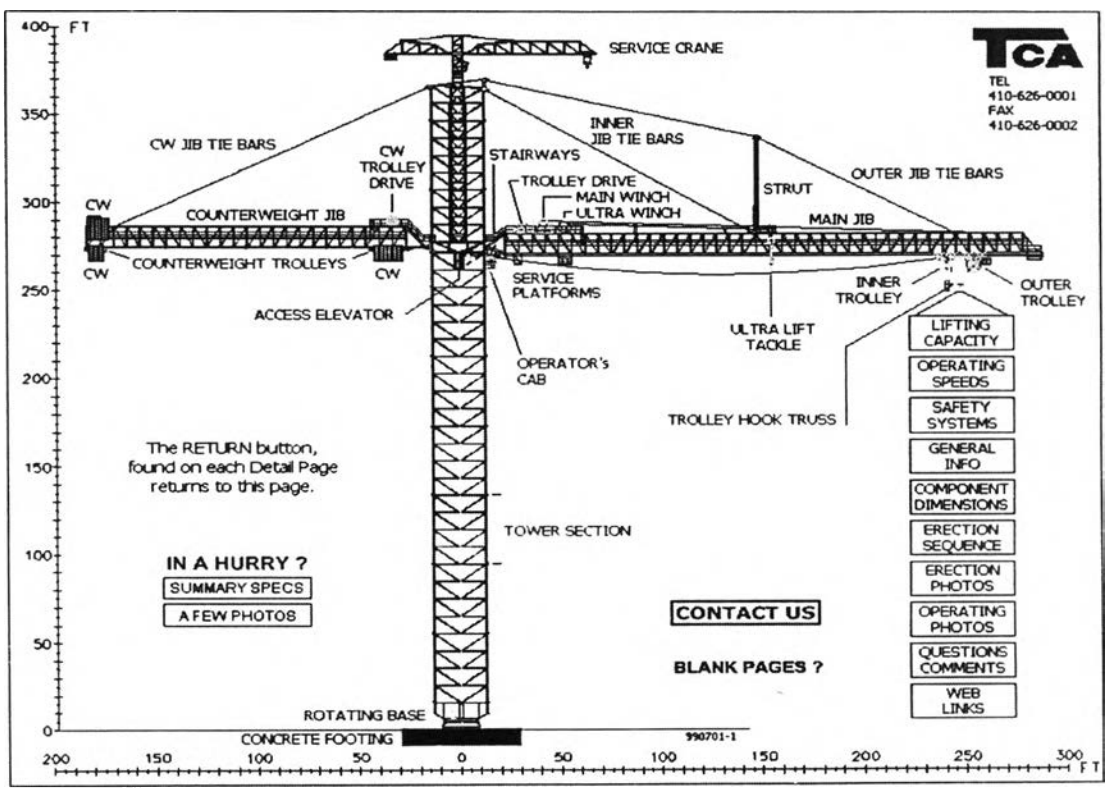
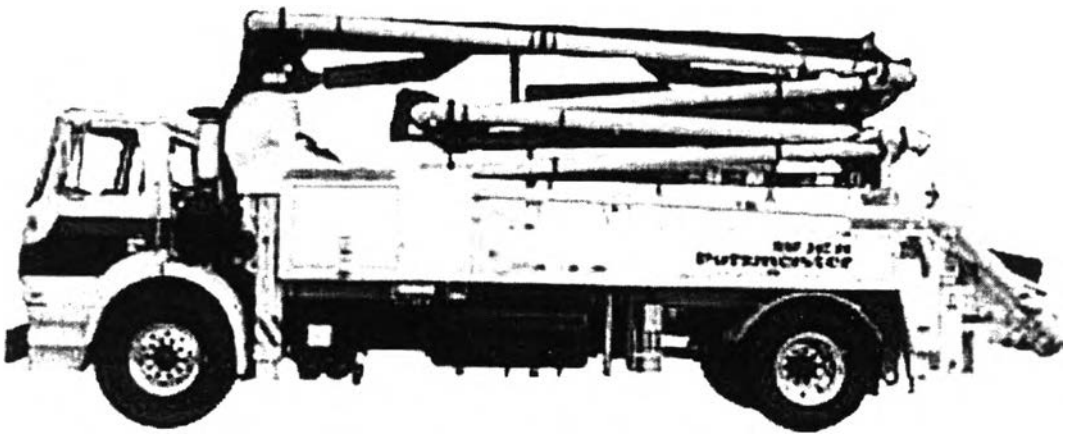
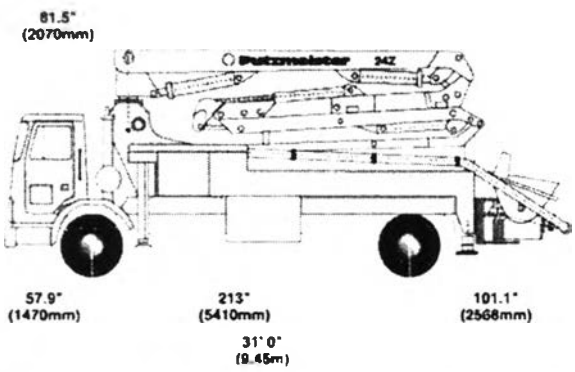


Figure A1-6: Information of dimensions of a tower crane (*www.crane.com*)

Truck-mounted Concrete Pump





Truck-Mounted Specifications		
Length	31 ft	(9.45r
Width	8 ft / 2 in	(2.50r
Height	12 ft / 4 in	(3.76r
Wheelbase	213 in	(5,410mr
Front axle weight	18,900 lbs	(8,573k
Rear axle weight	19,100 lbs	(8,663k
Approx total weight	38,000 lbs	(17,236k

Figure A1-7: Information of a truck-mounted concrete pump

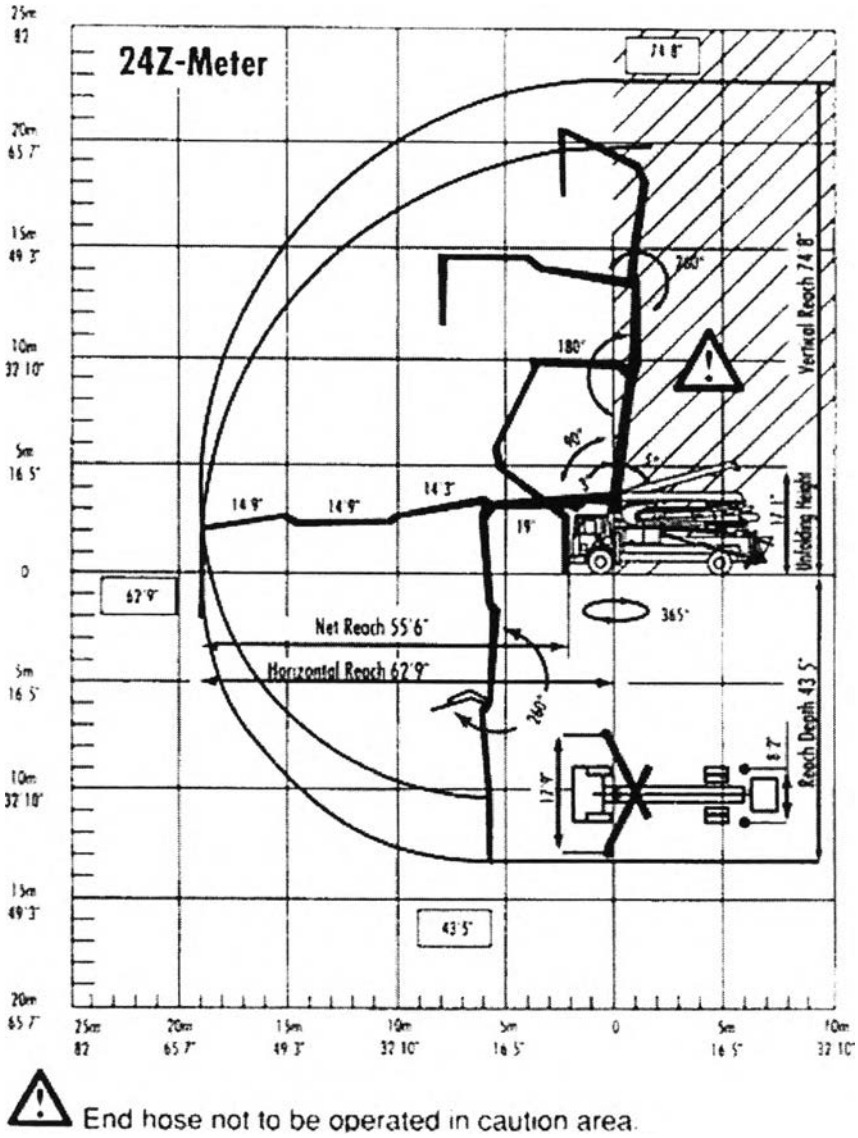
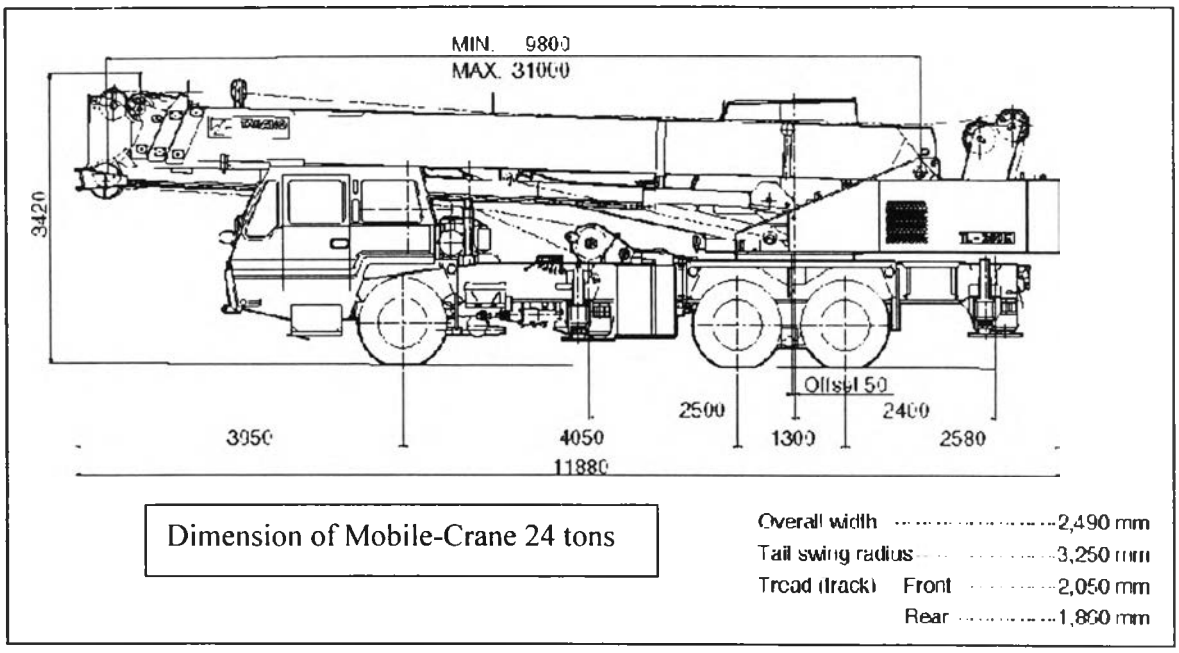


Table of Productivity

Pump	Max Theory Output	Max Pressure
.09	117 yd^3/hr (90 m^3/hr)	1015 psi (70 bar) - Rod Side
.12 L	142 yd^3/hr (109 m^3/hr)	1015 psi (70 bar) - Rod Side

Figure A1-8: Information of a truck-mounted concrete pump (*www.putzmeister.com*)



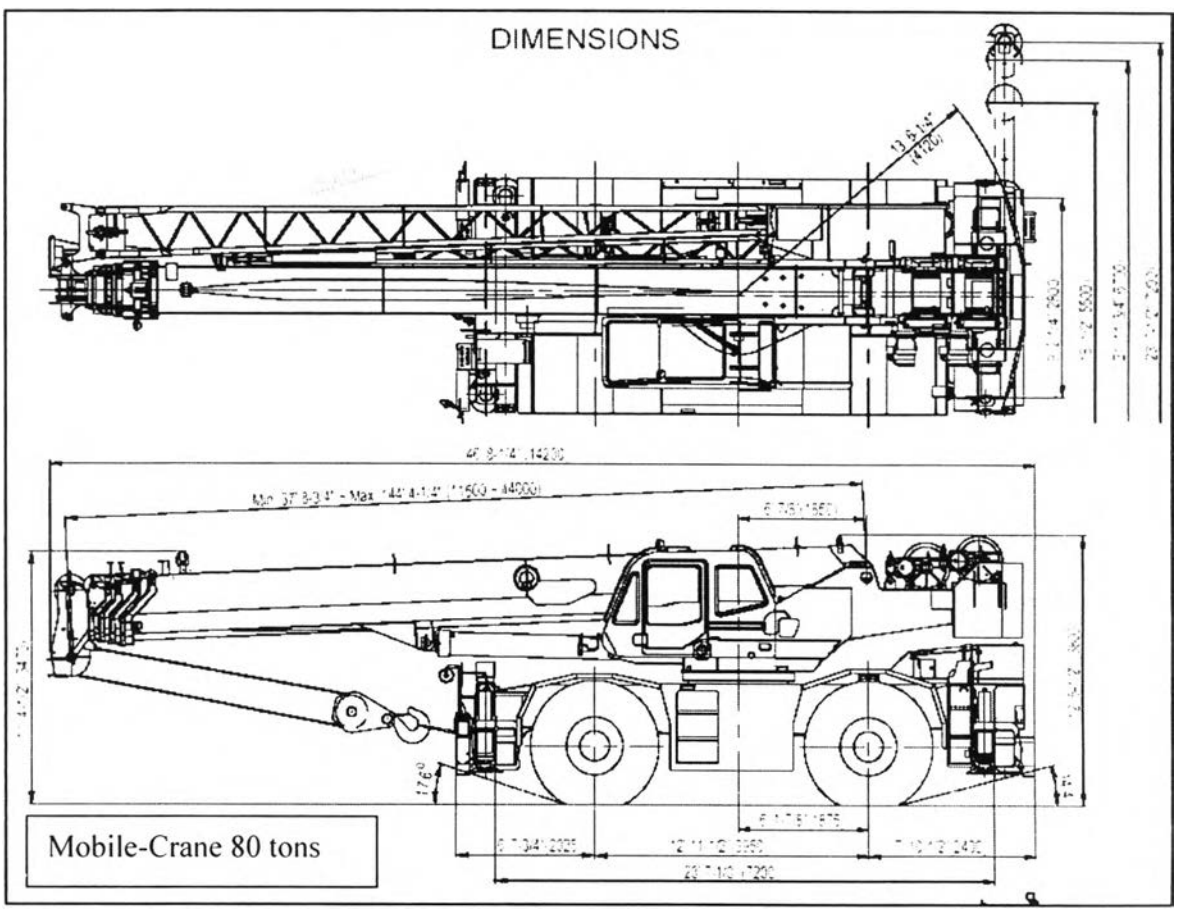


Figure A1-9: Information of a mobile-crane

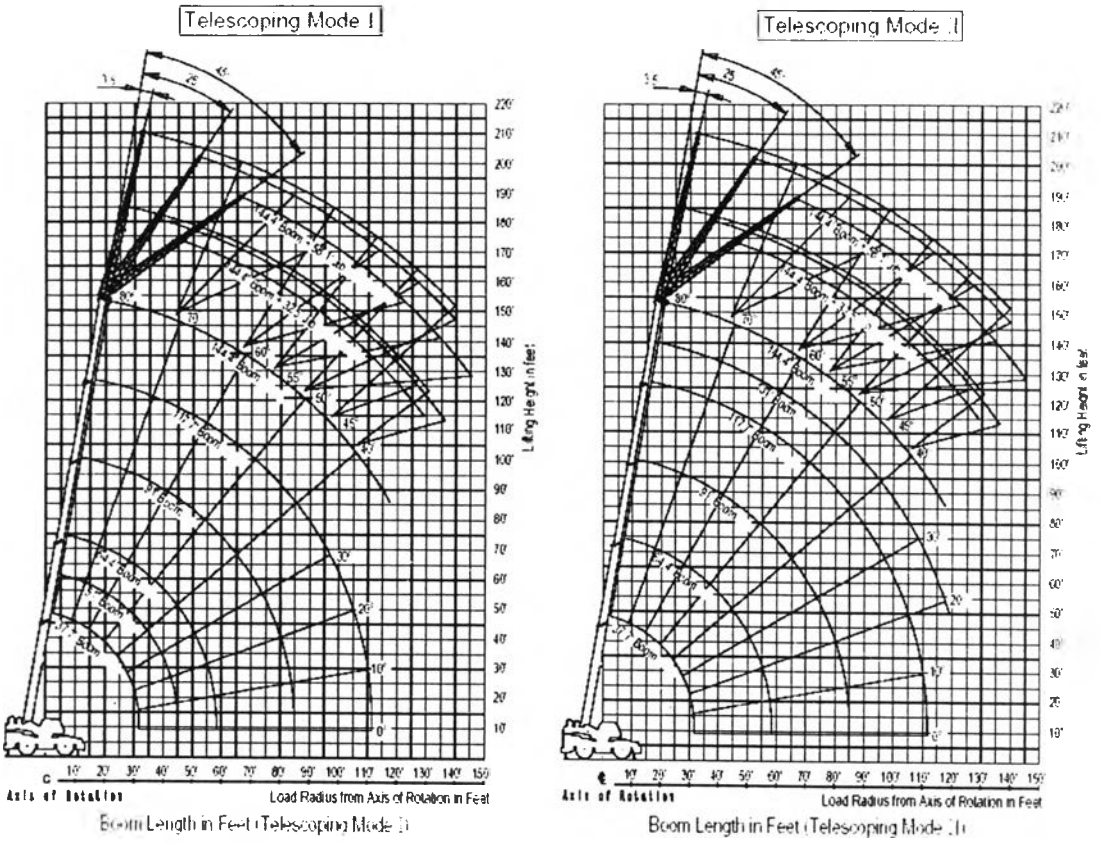
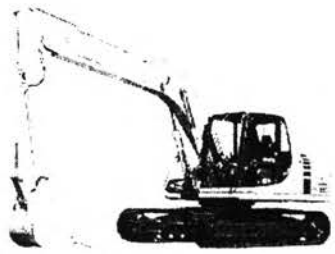
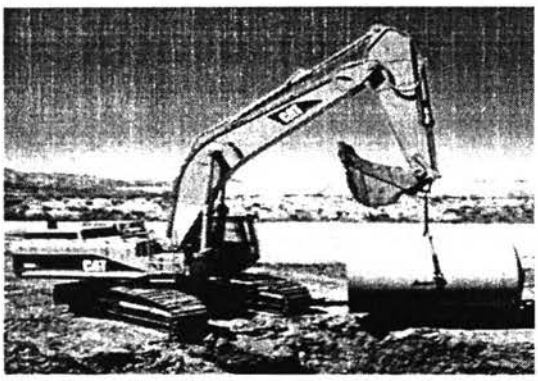
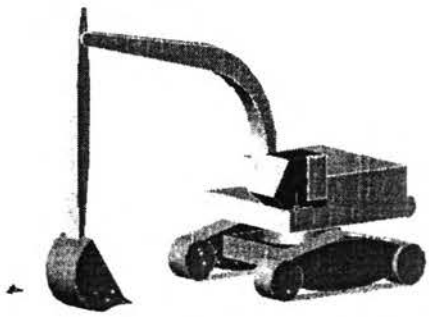
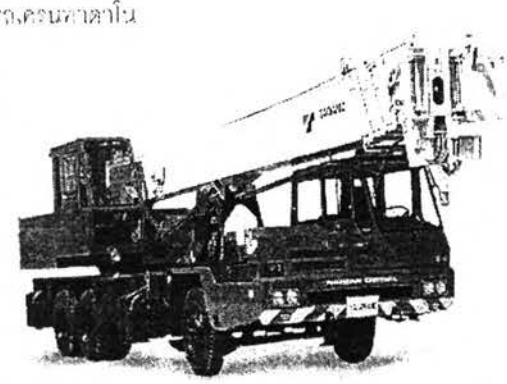
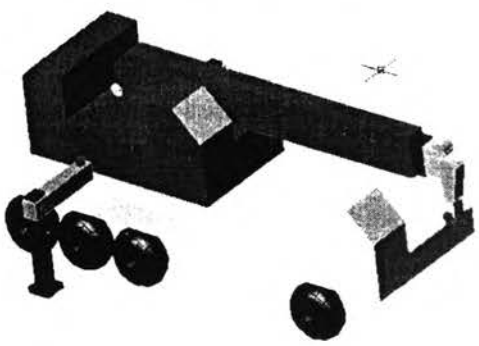
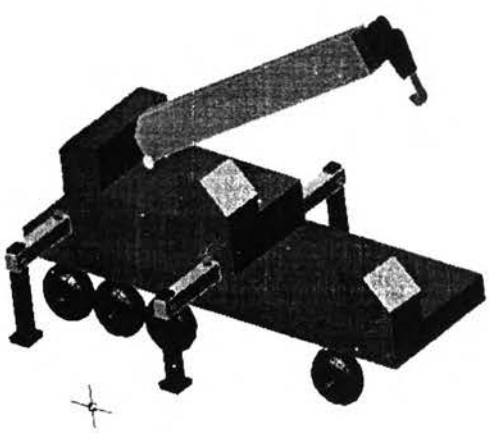
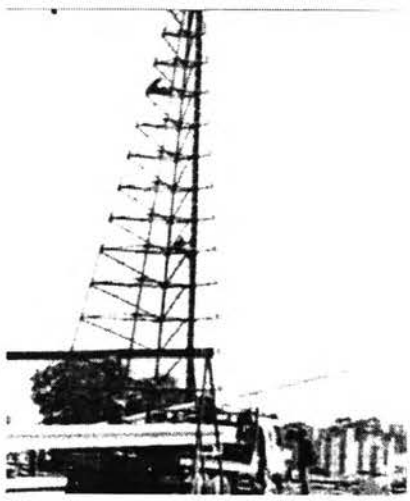
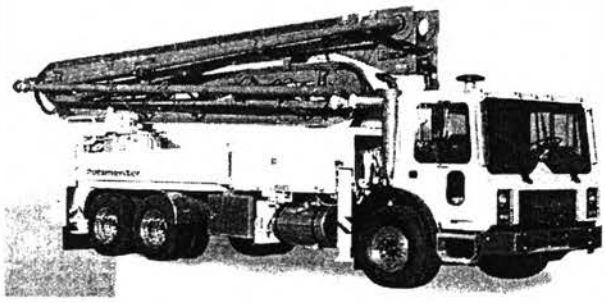
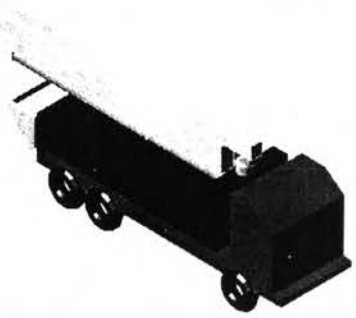
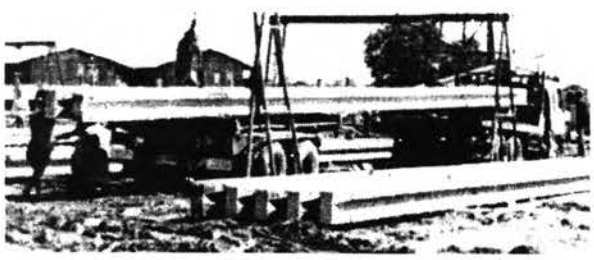


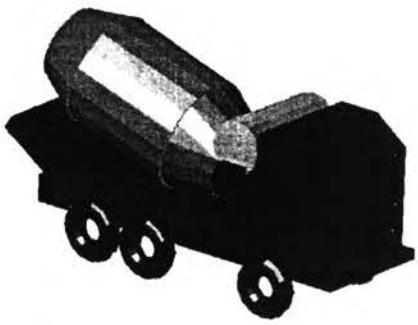
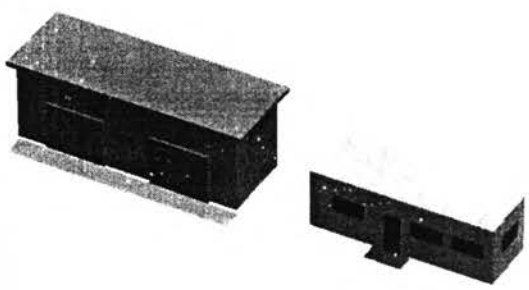
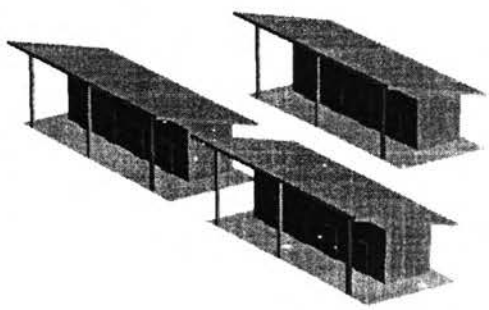
Figure A1-10: Information of a mobile-crane (*Continue*)

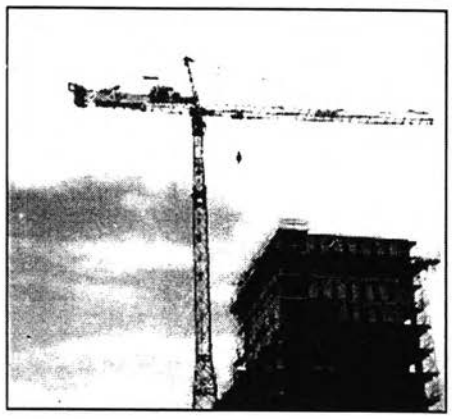
Appendix 2

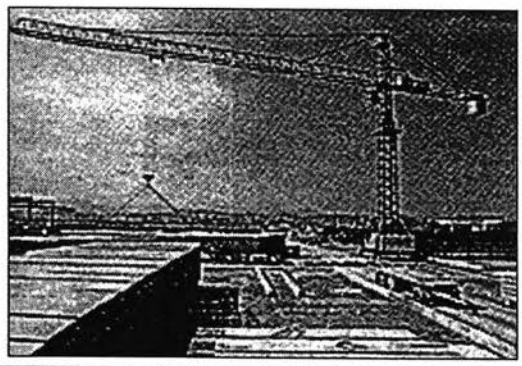
Static Models of Construction Machines and Facilities Generated by CAD Software

PC120-6 	
	
TADANO 	
	

Construction Machines	3D Static Models Generated by CAD
	
	
	
	

Construction Machines	3-D Studio Models
	
	
	
	





3D Static Models Generated by CAD

Appendix 3

Hierarchical Structures of Construction Machine Models

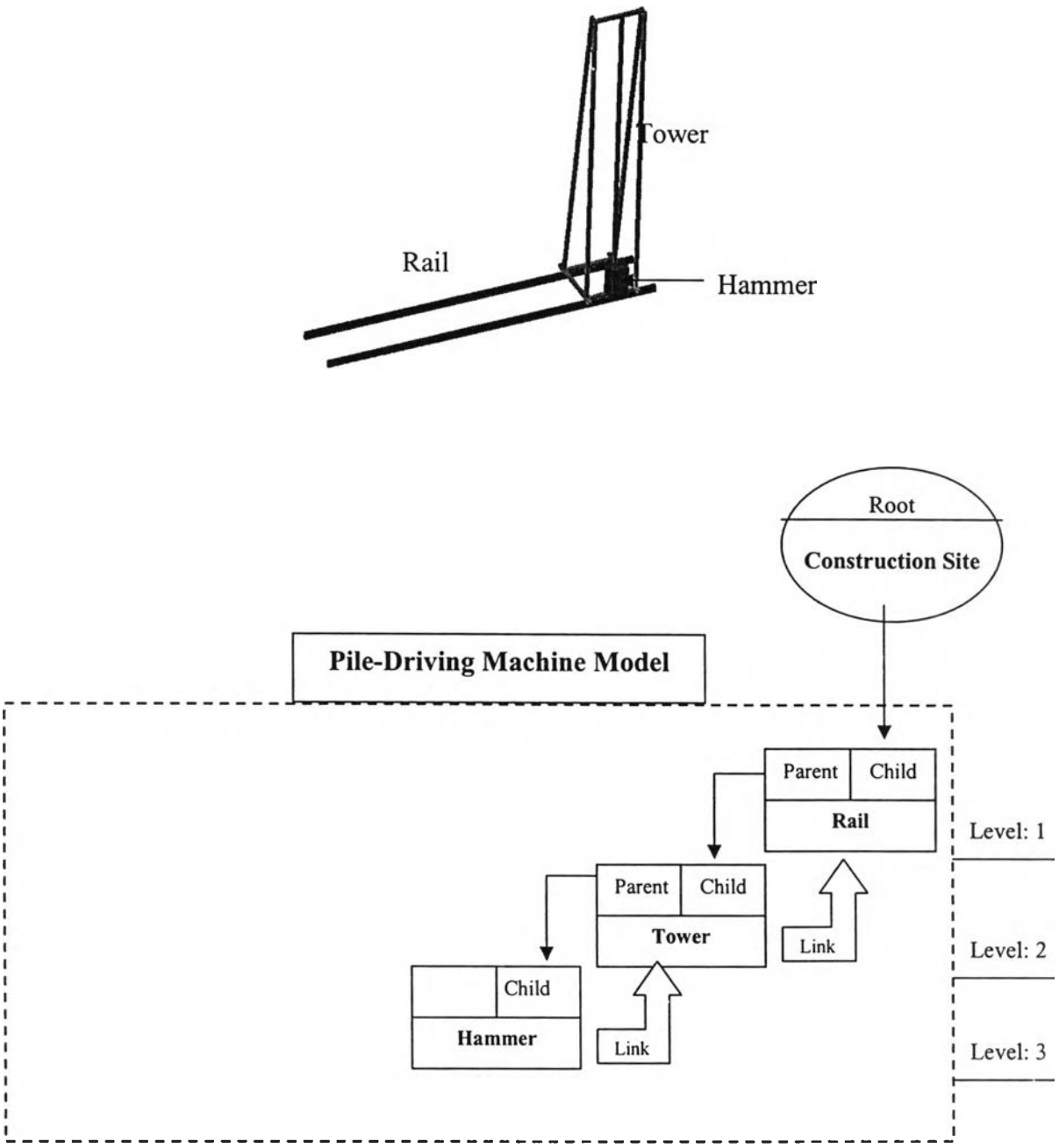


Figure A3-1: Family-tree and hierarchical structure of a ***pile-driving machine*** model

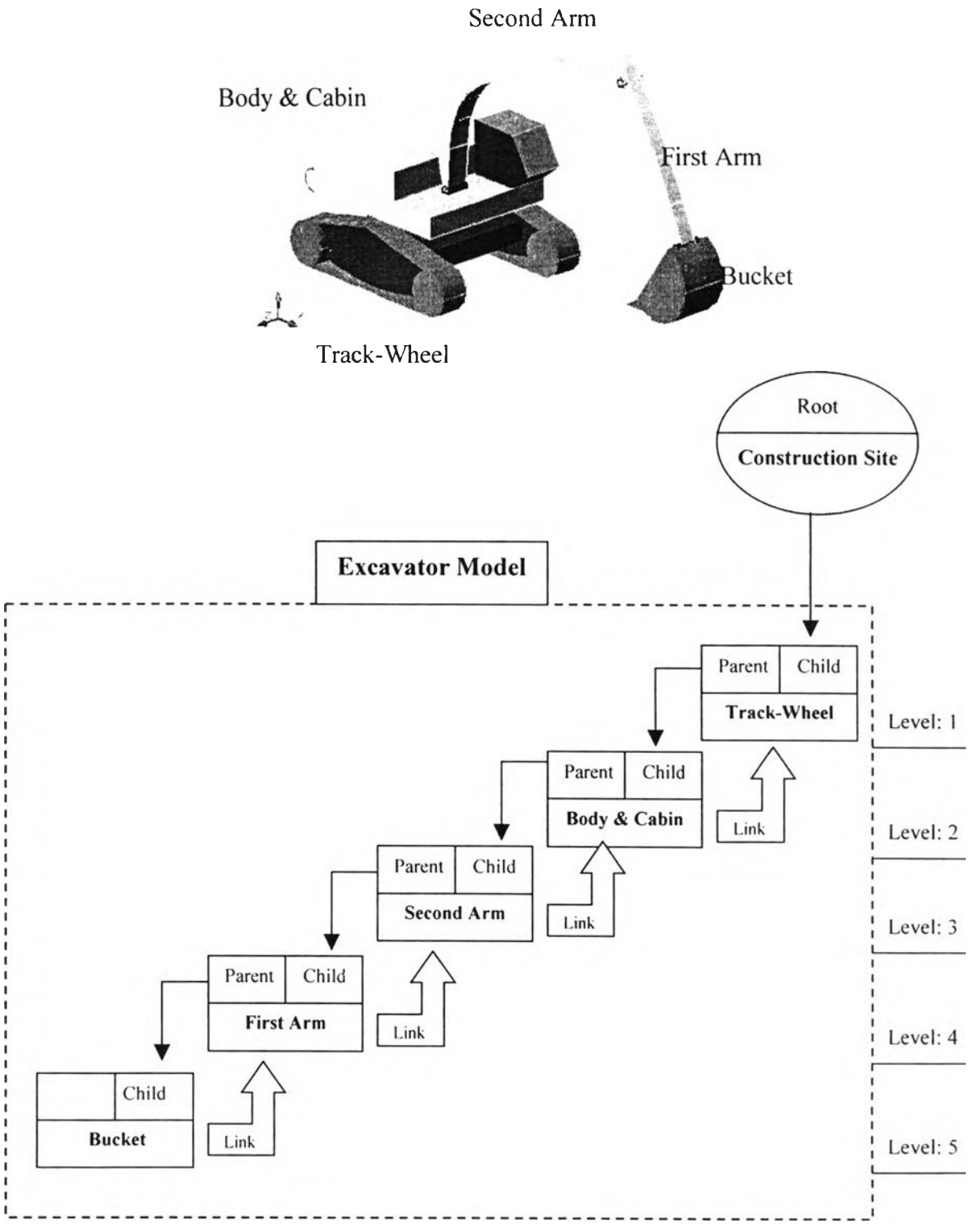
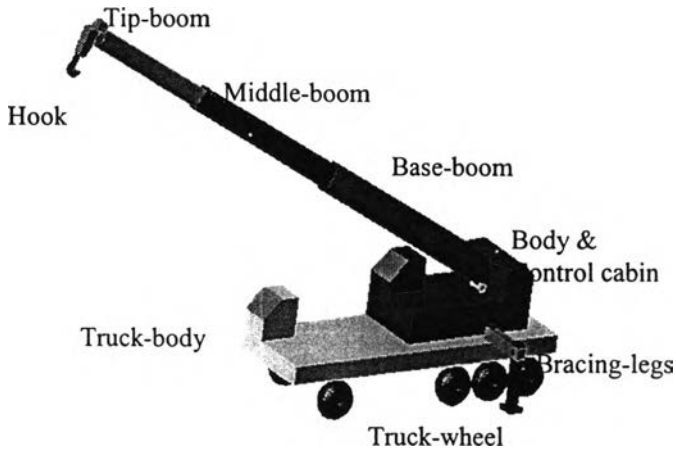


Figure A3-2: Family-tree and hierarchical structure of an ***excavator*** model



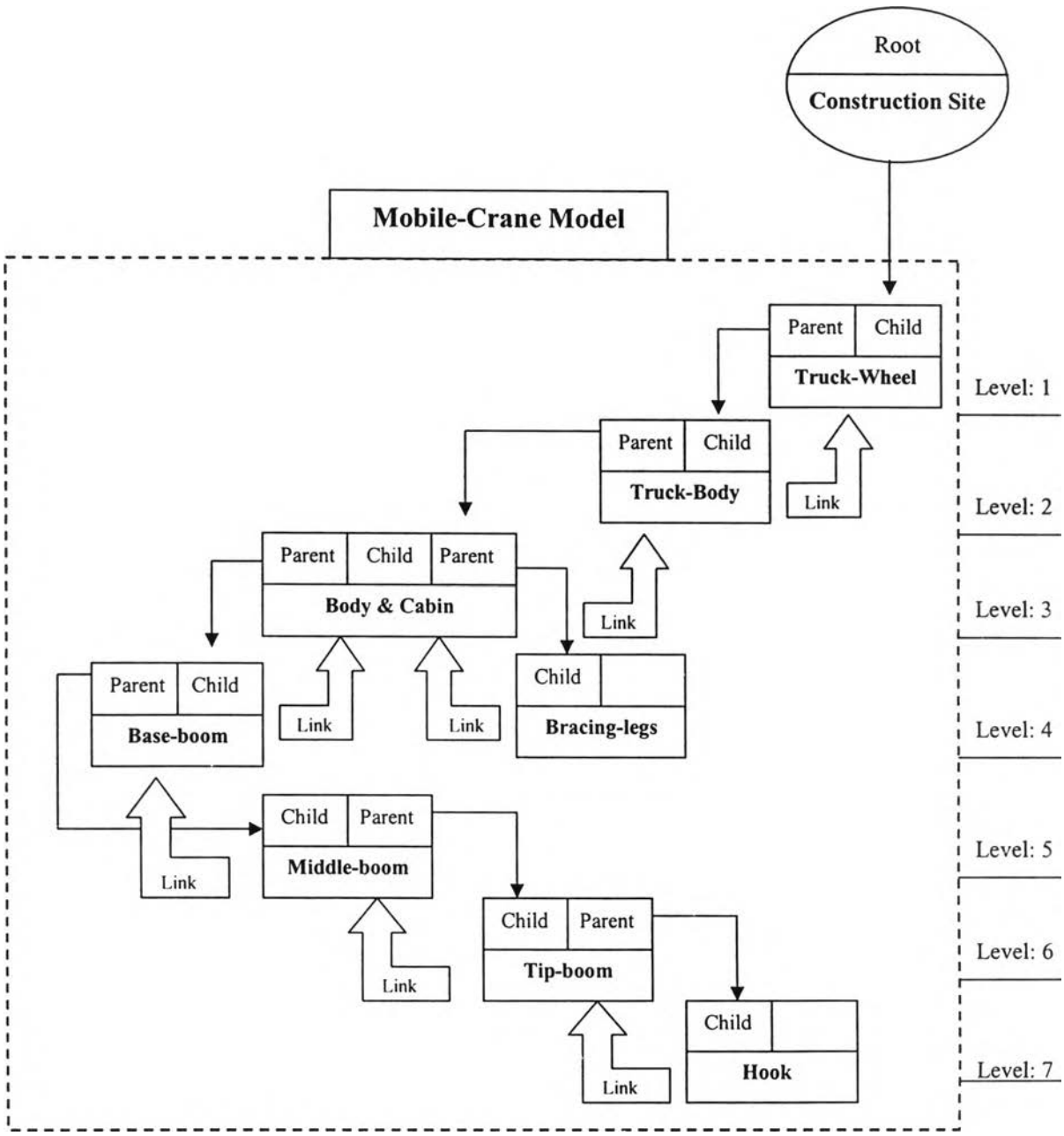
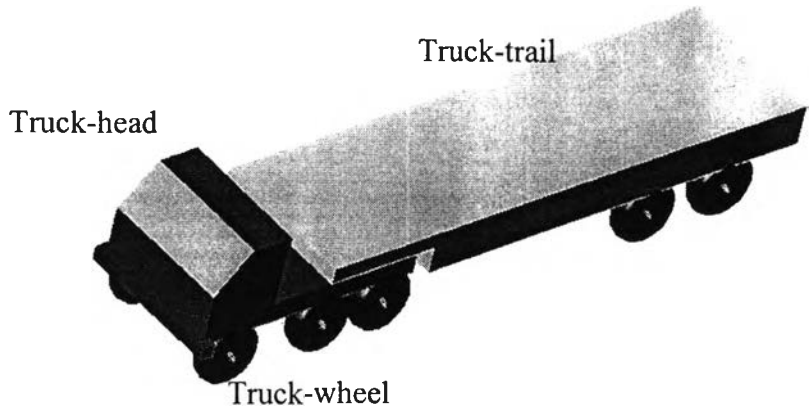


Figure A3-3: Family-tree and hierarchical structure of a ***mobile-crane*** model



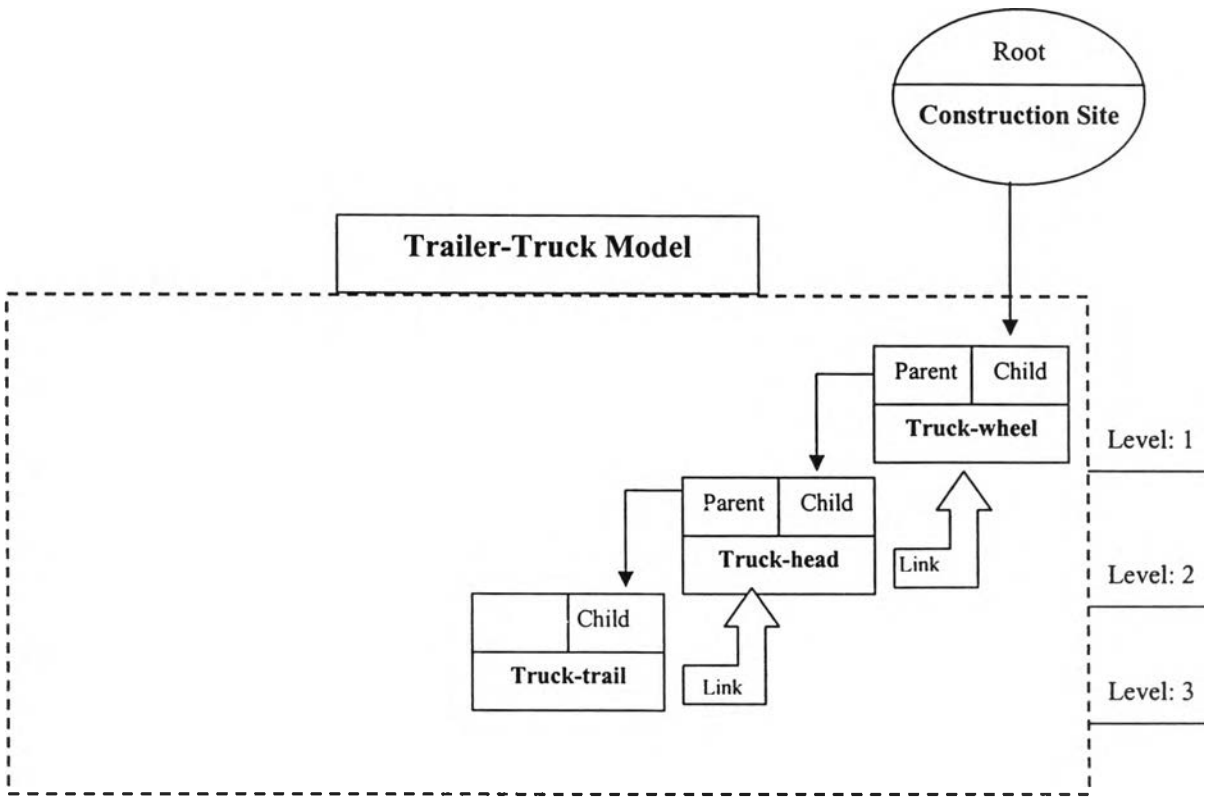


Figure A3-4: Family-tree and hierarchical structure of a ***trailer-truck*** model

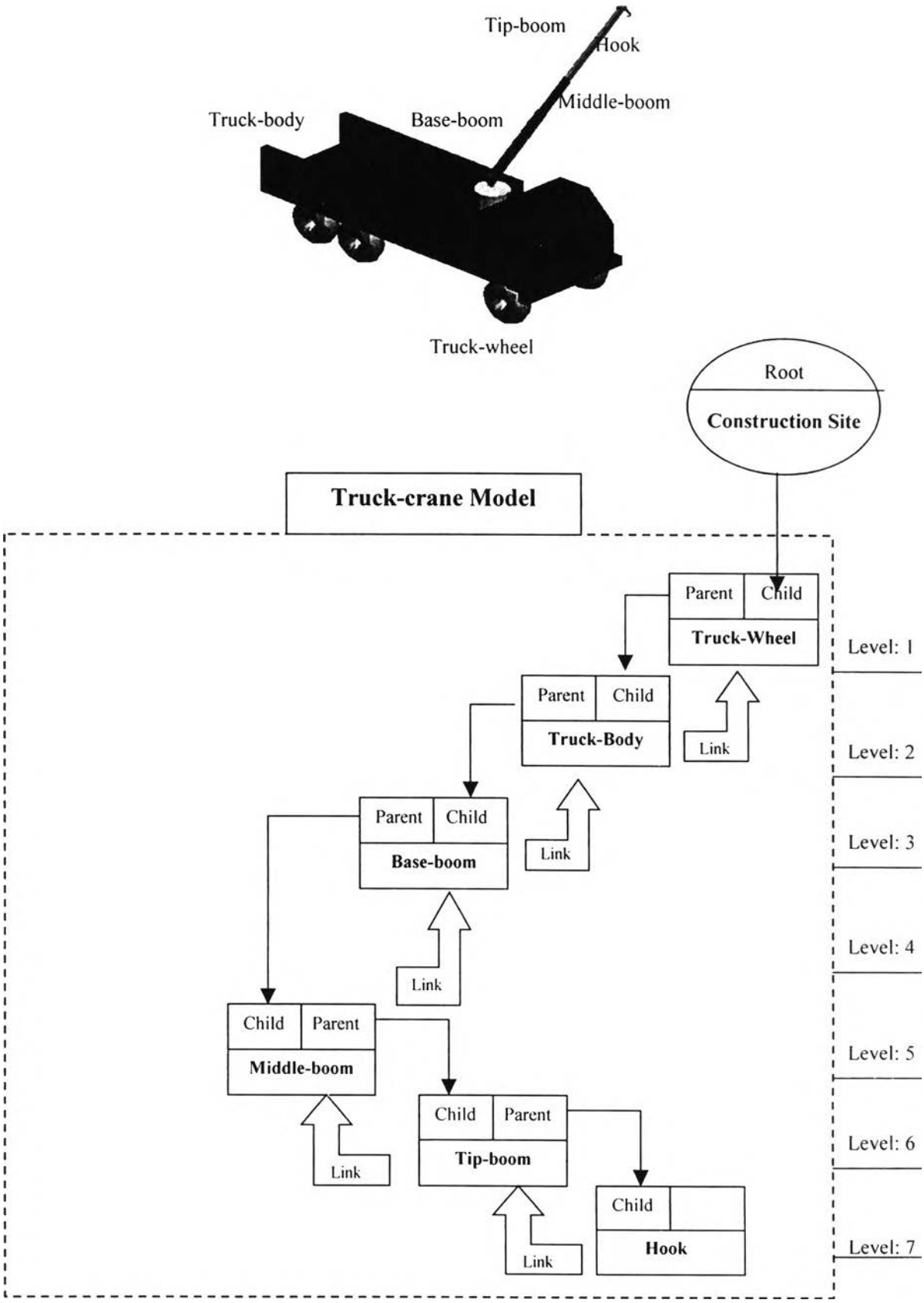
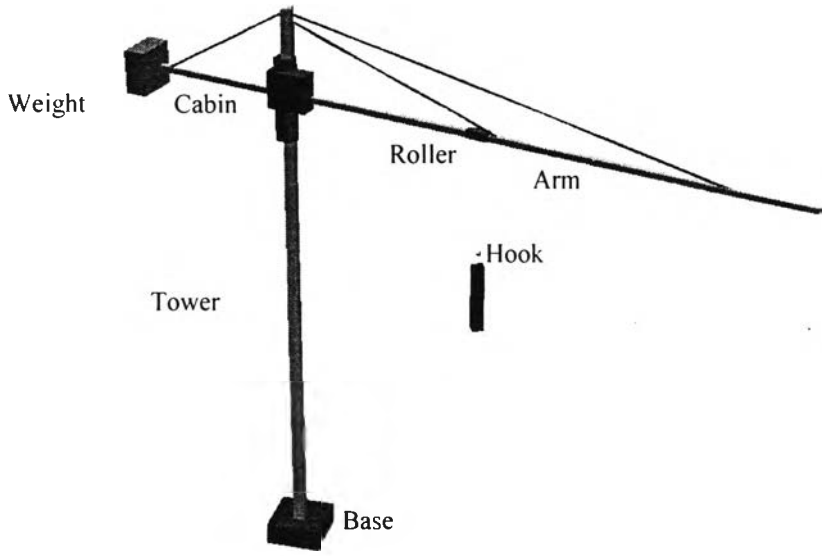


Figure A3-5: Family-tree and hierarchical structure of a ***truck-crane*** model



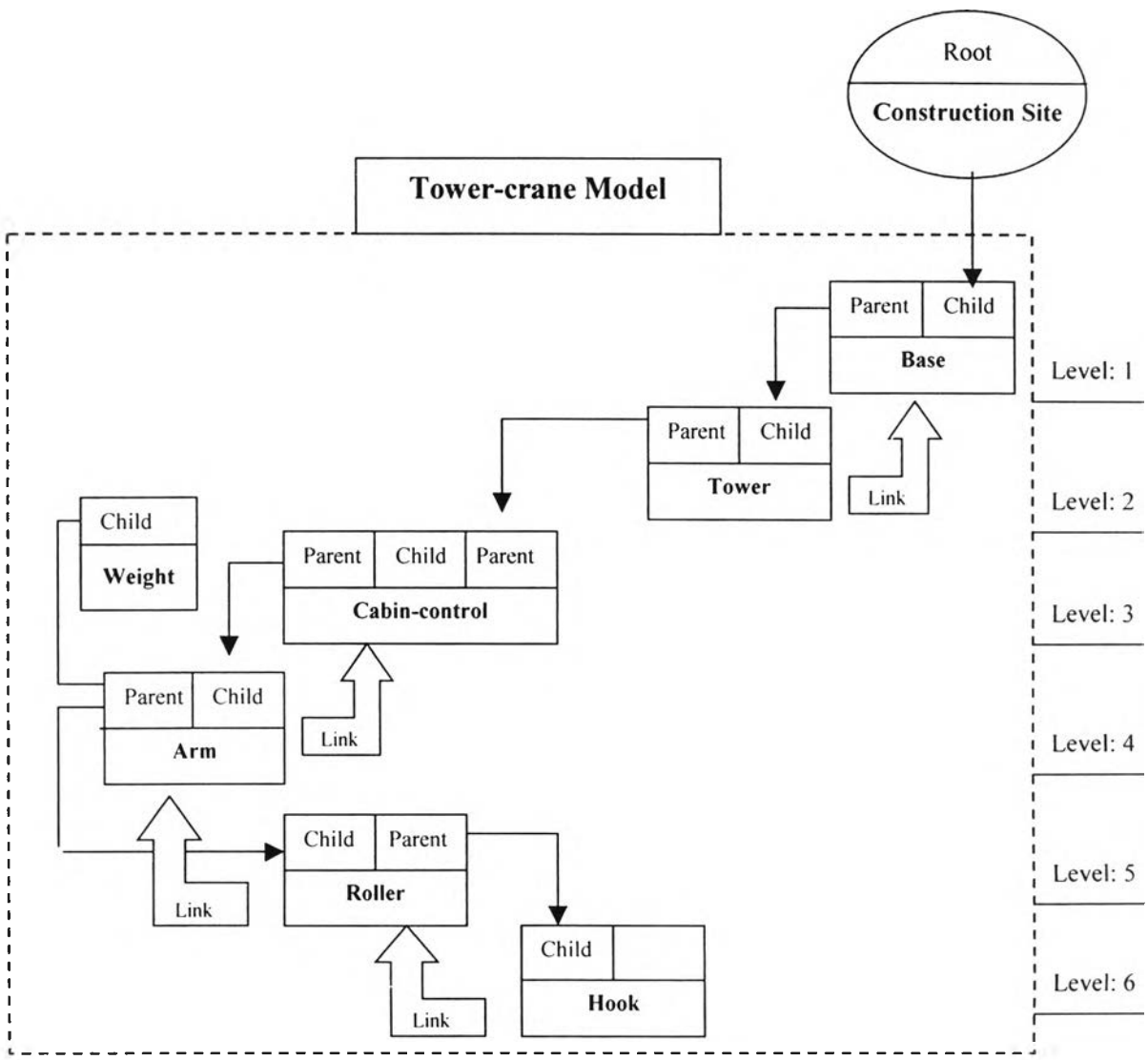
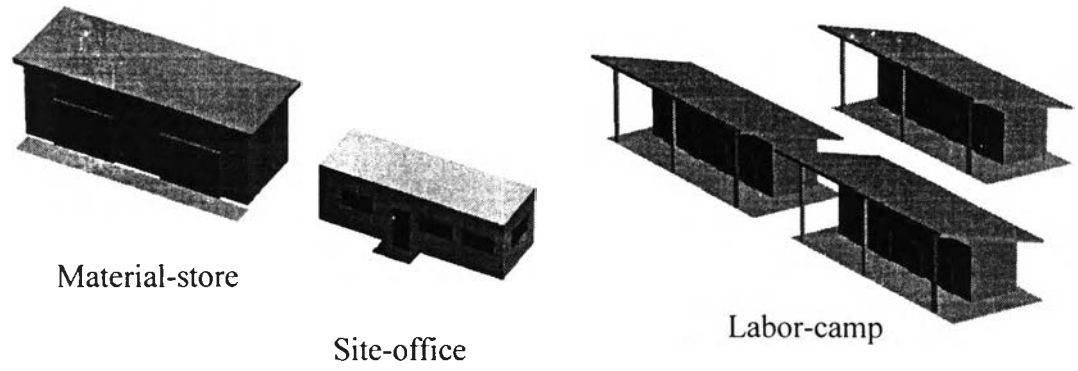


Figure A3-6: Family-tree and hierarchical structure of a ***tower-crane*** model



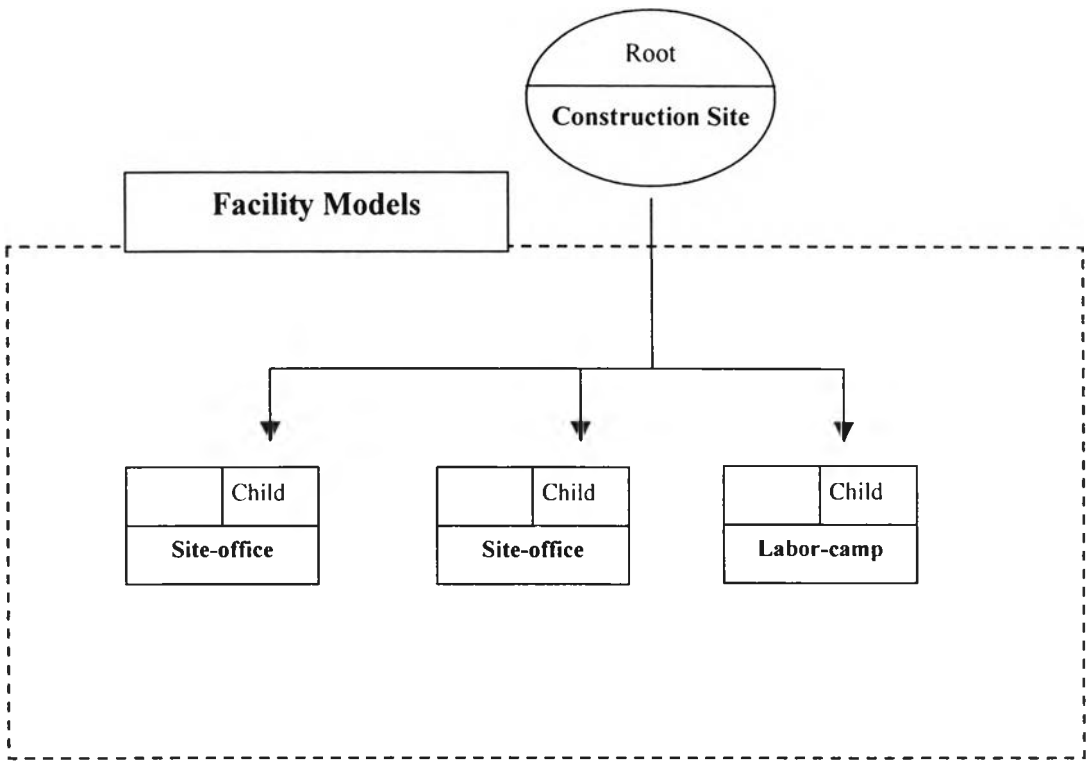


Figure A3-7: Family-tree and hierarchical structure of ***facility*** models

Appendix 4

Controlling Parameters of Factory-Construction Activities

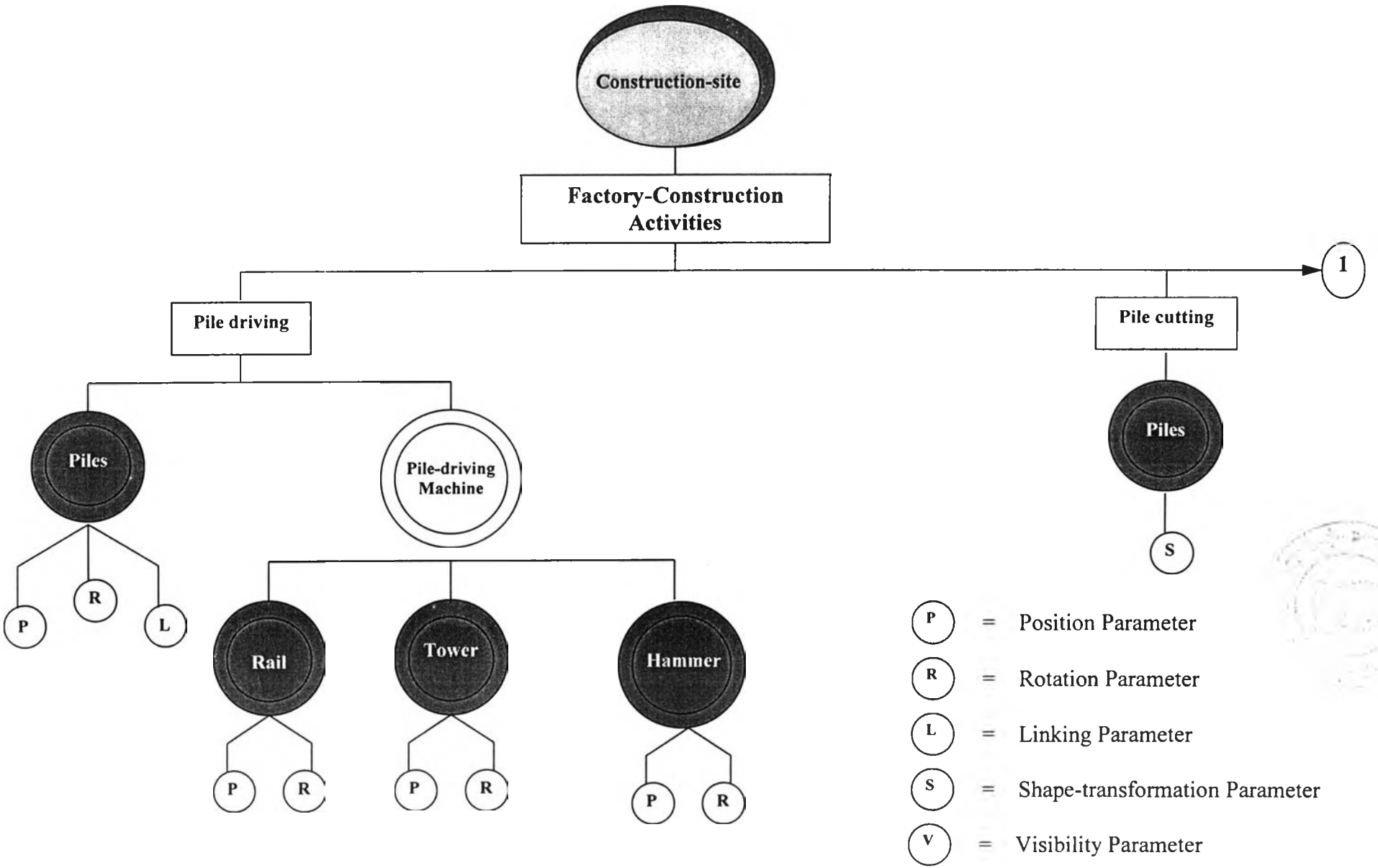


Figure A4-1: The controlling parameters of factory-construction activities

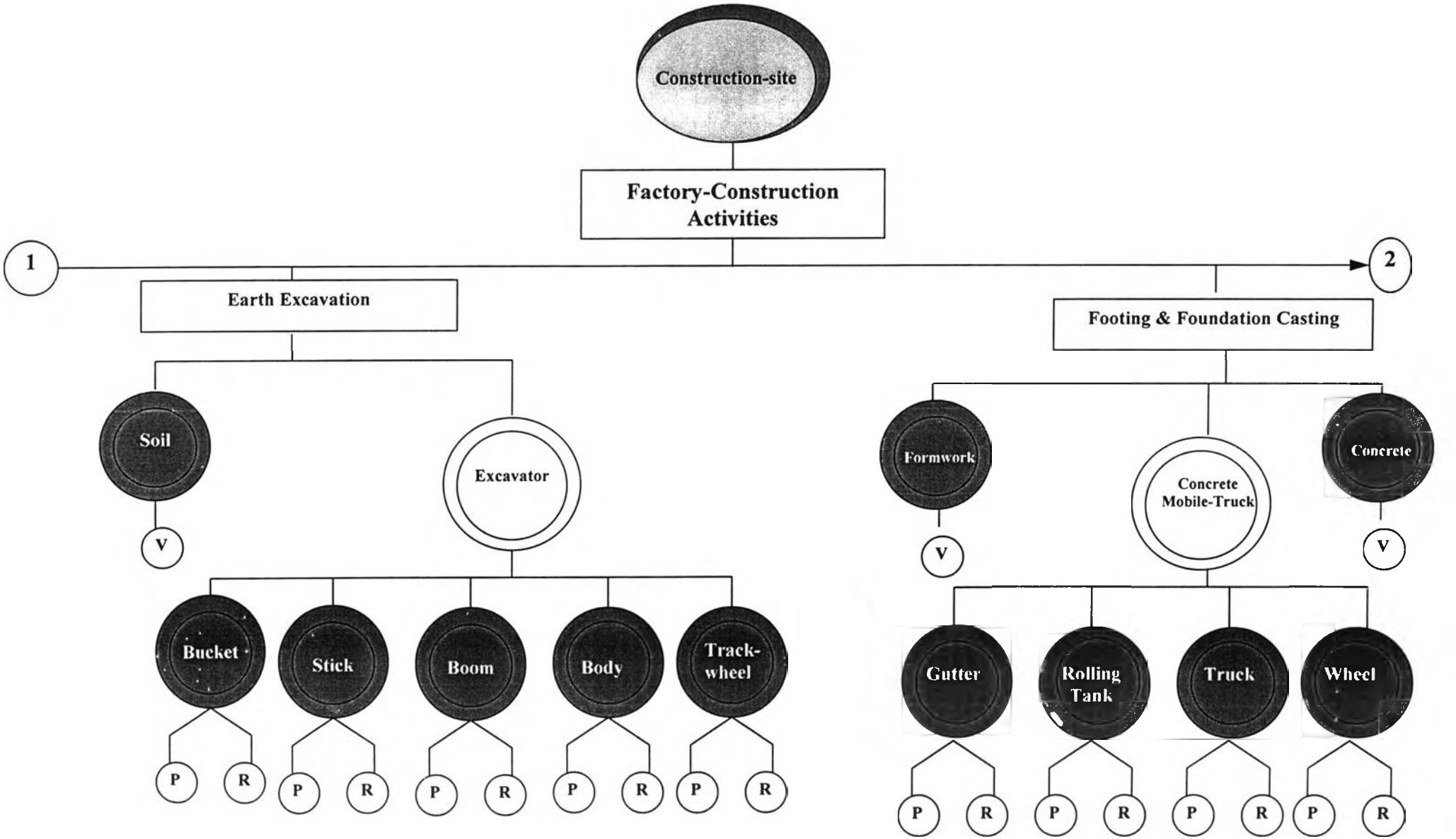


Figure A4-2: The controlling parameters of factory-construction activities (*continue*)

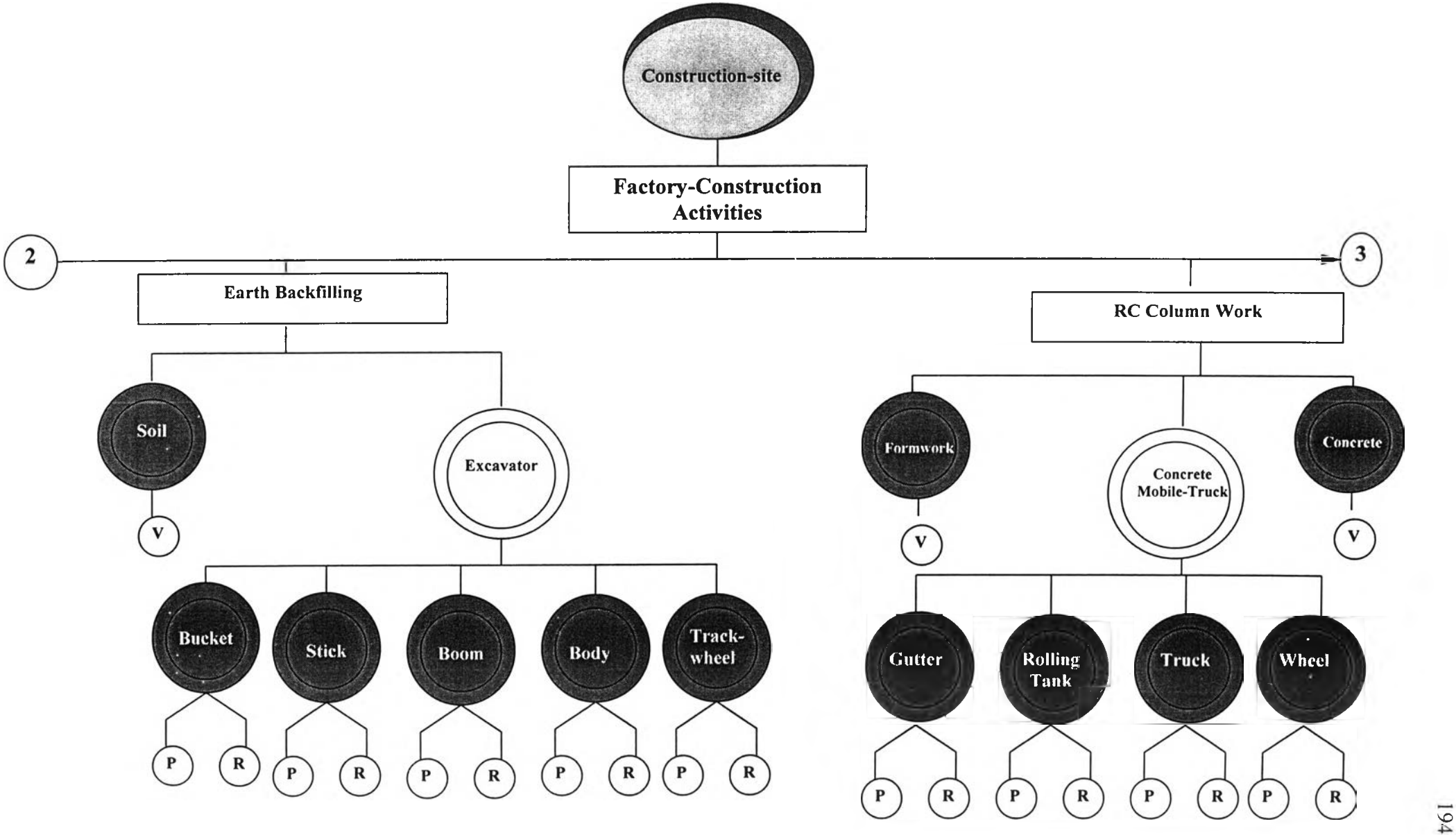


Figure A4-3: The controlling parameters of factory-construction activities (*continue*)

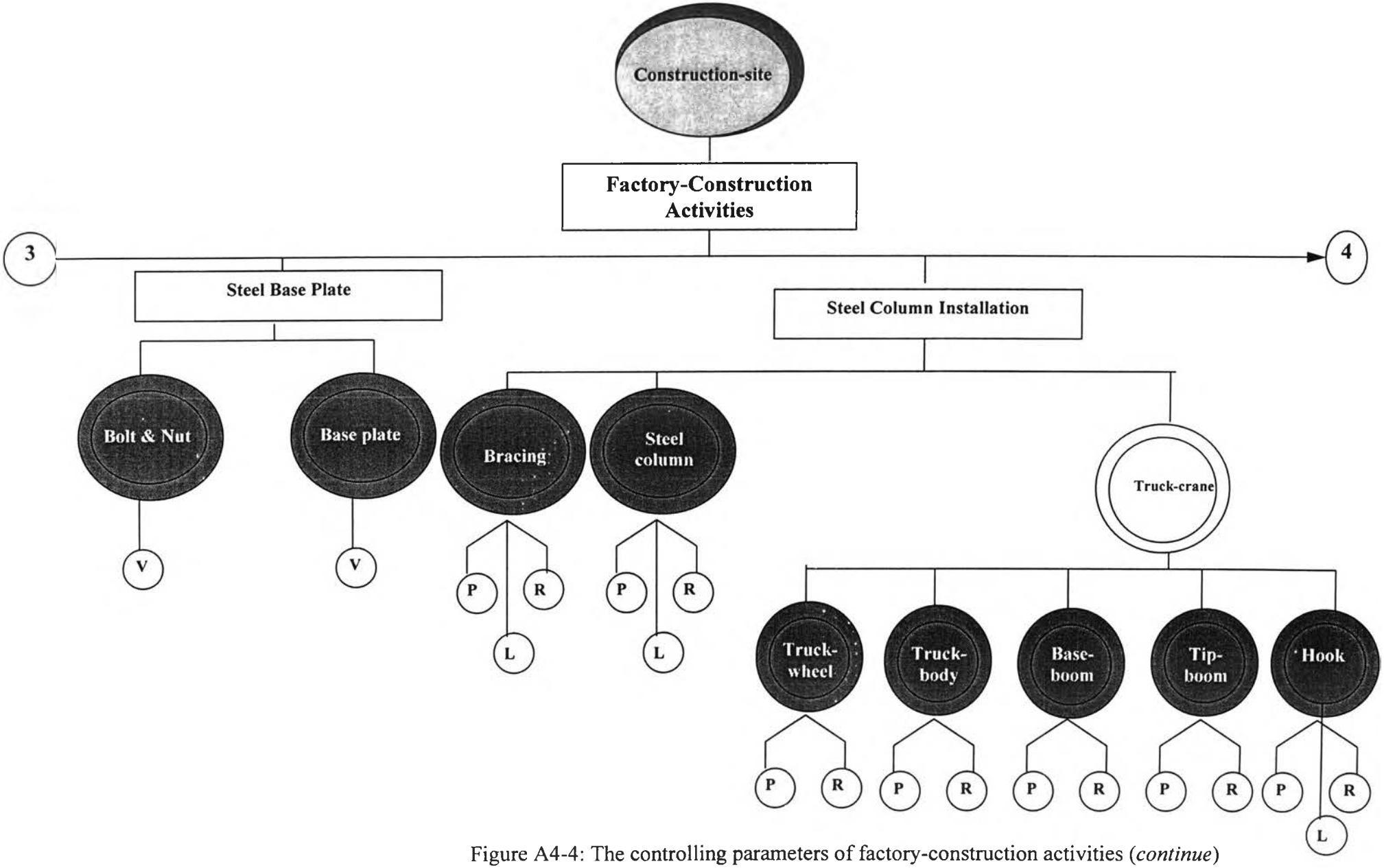


Figure A4-4: The controlling parameters of factory-construction activities (*continue*)

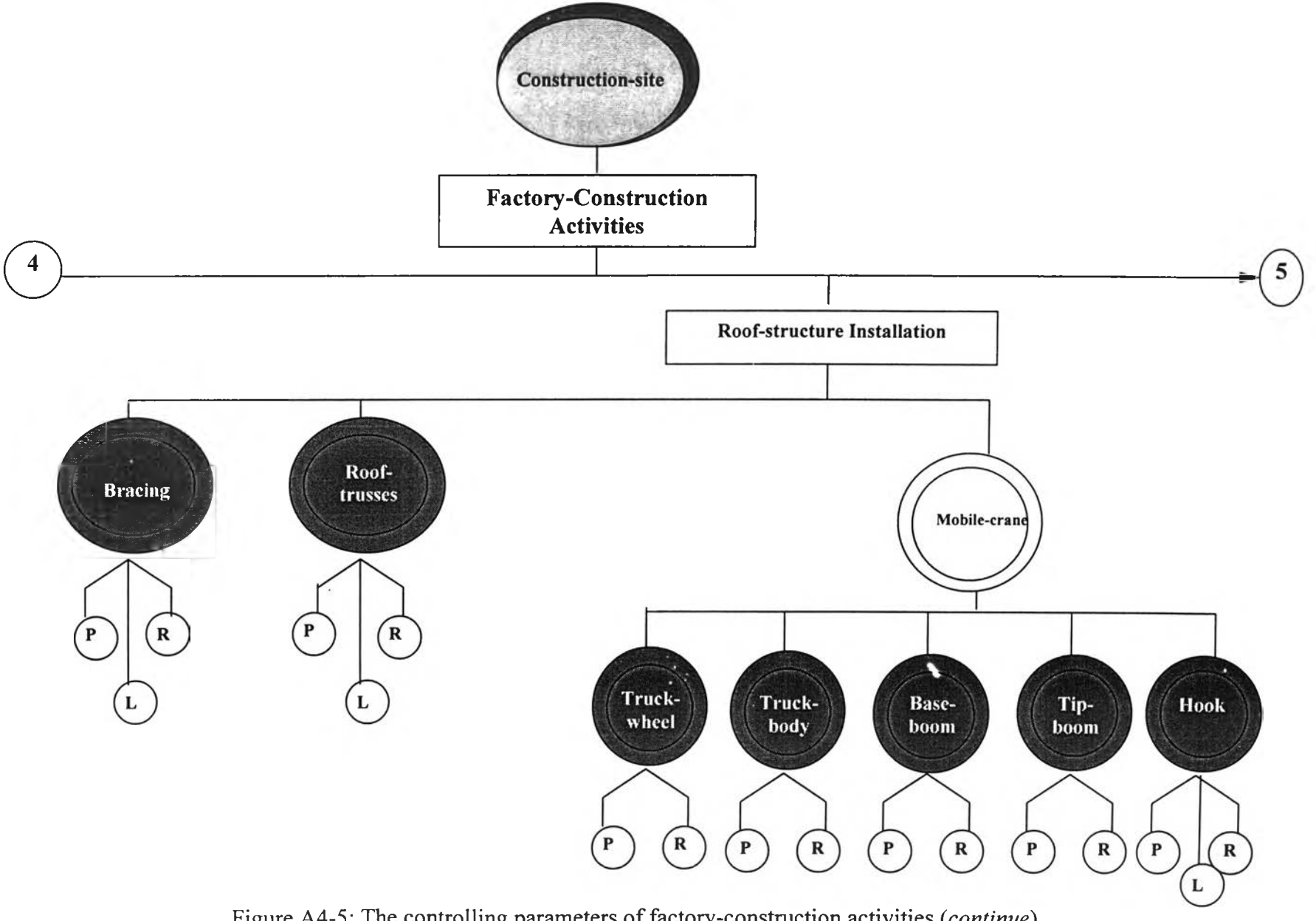


Figure A4-5: The controlling parameters of factory-construction activities (*continue*)

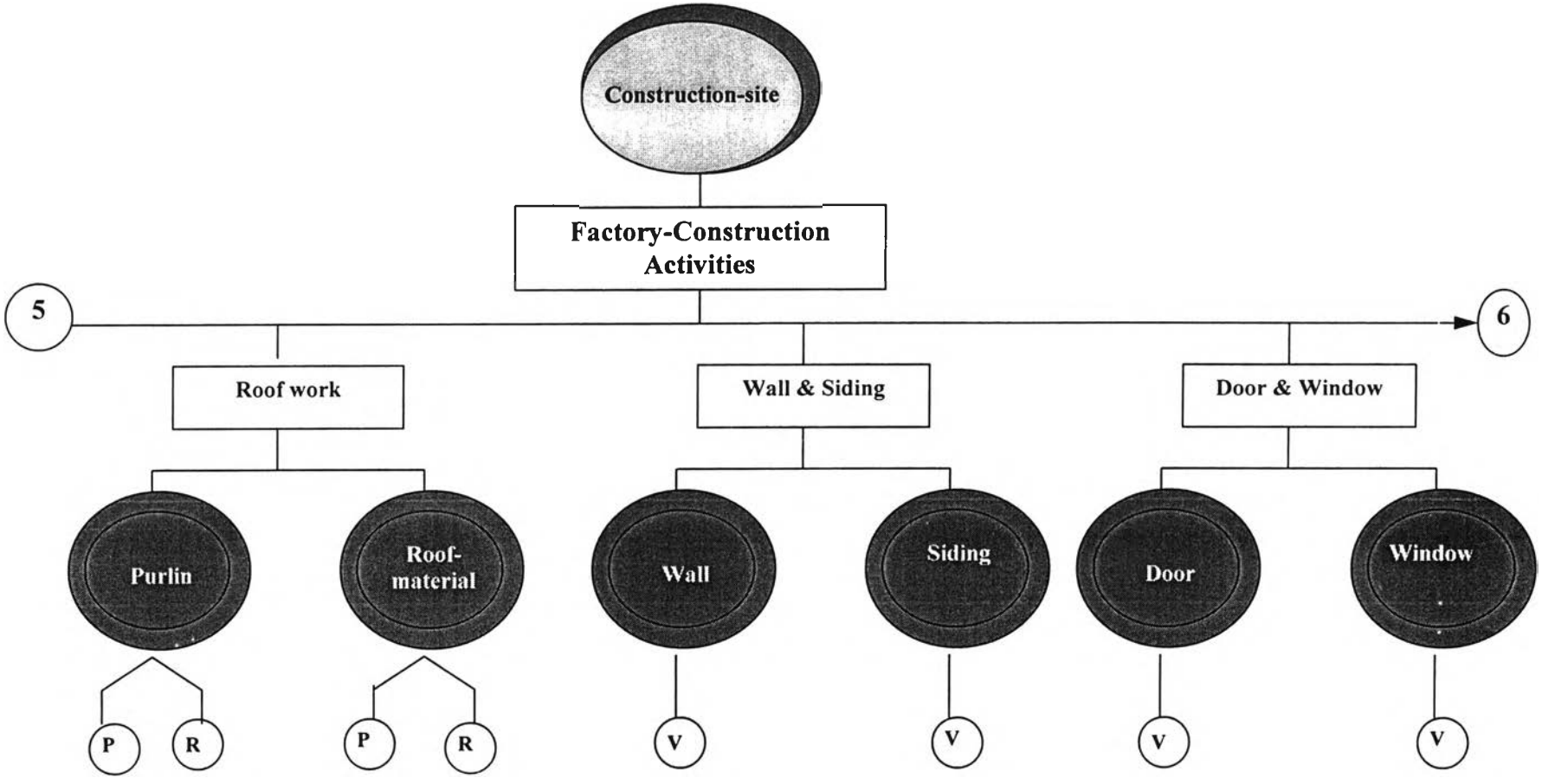


Figure A4-6: The controlling parameters of factory-construction activities (*continue*)

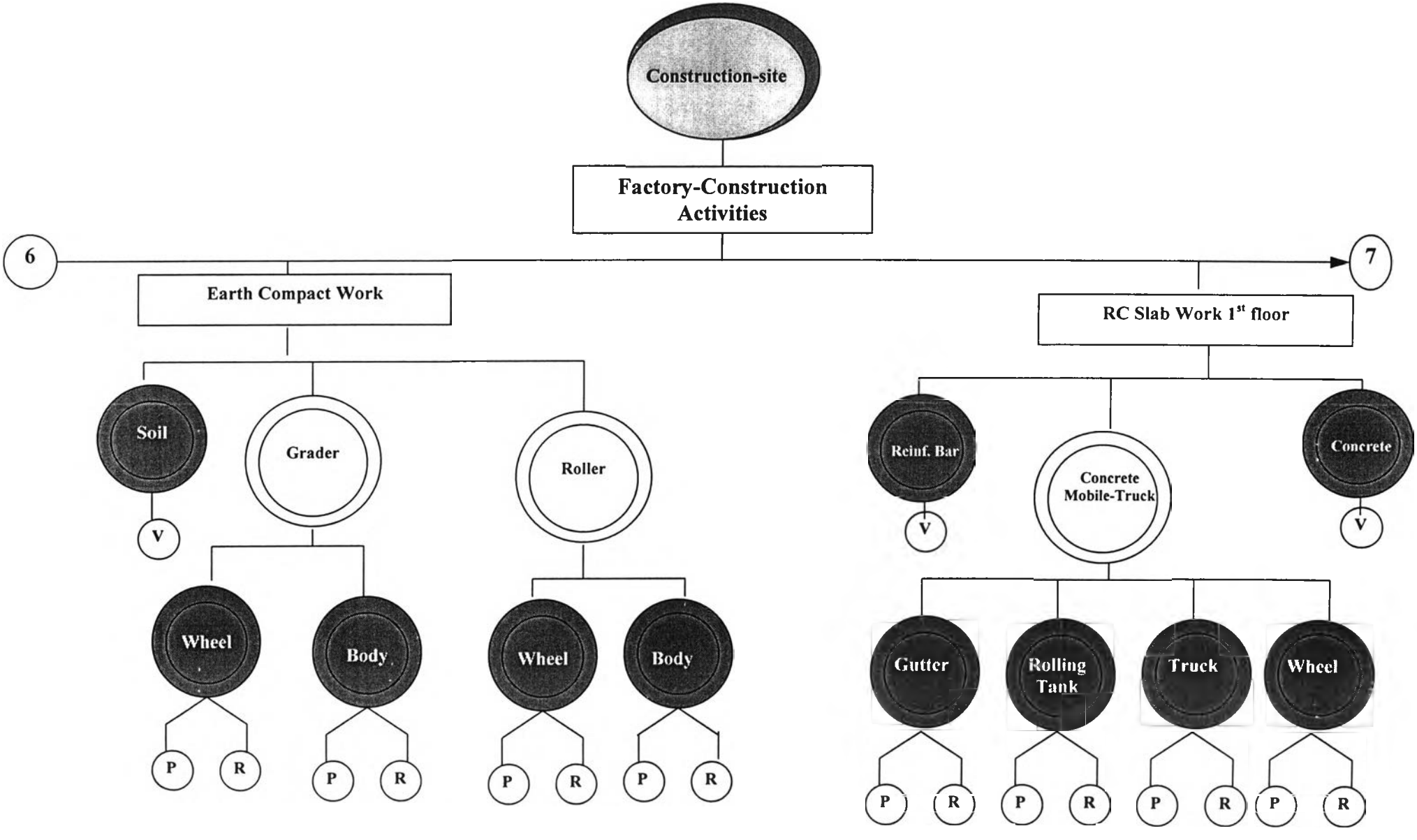


Figure A4-7: The controlling parameters of factory-construction activities (*continue*)

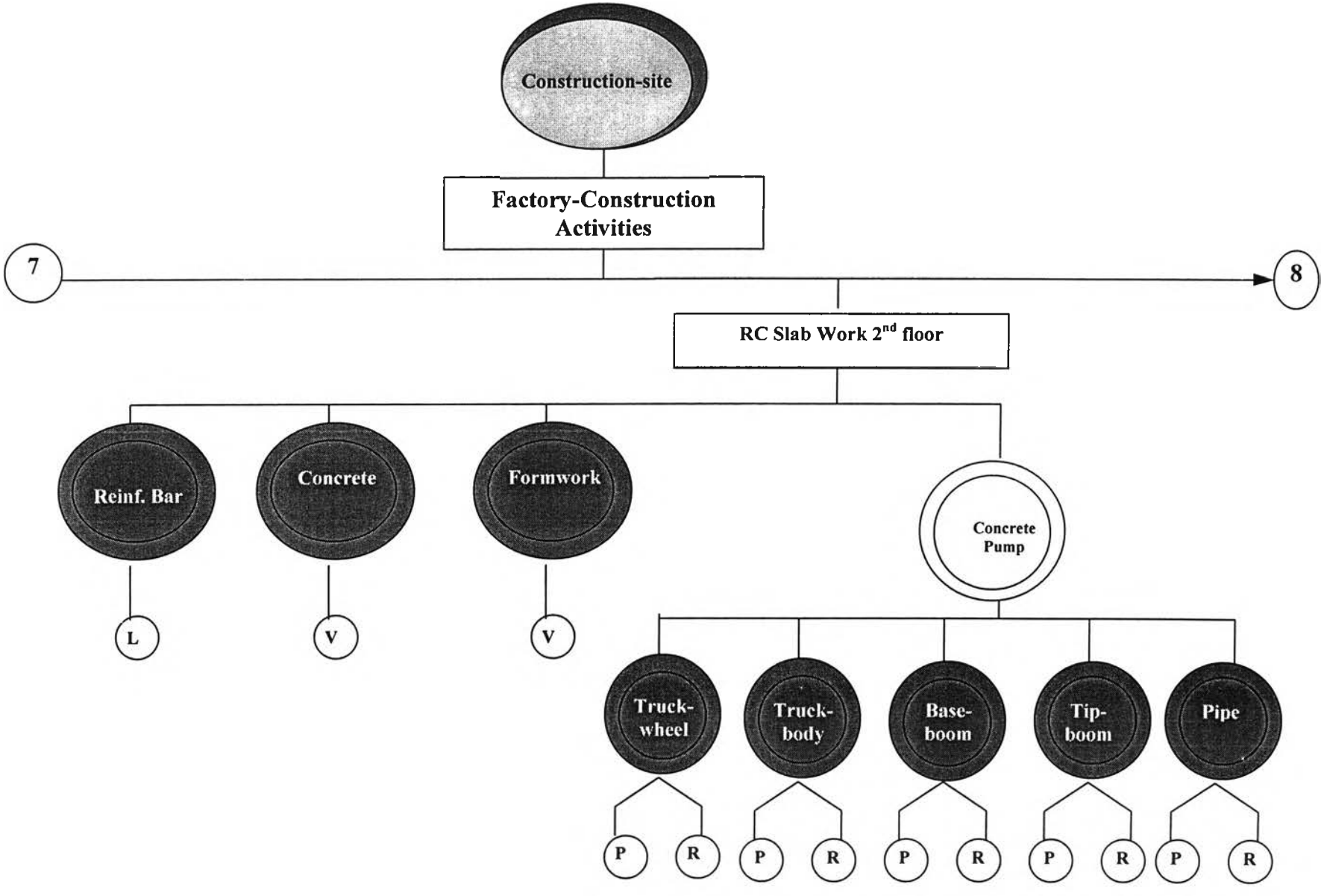


Figure A4-8: The controlling parameters of factory-construction activities (*continue*)

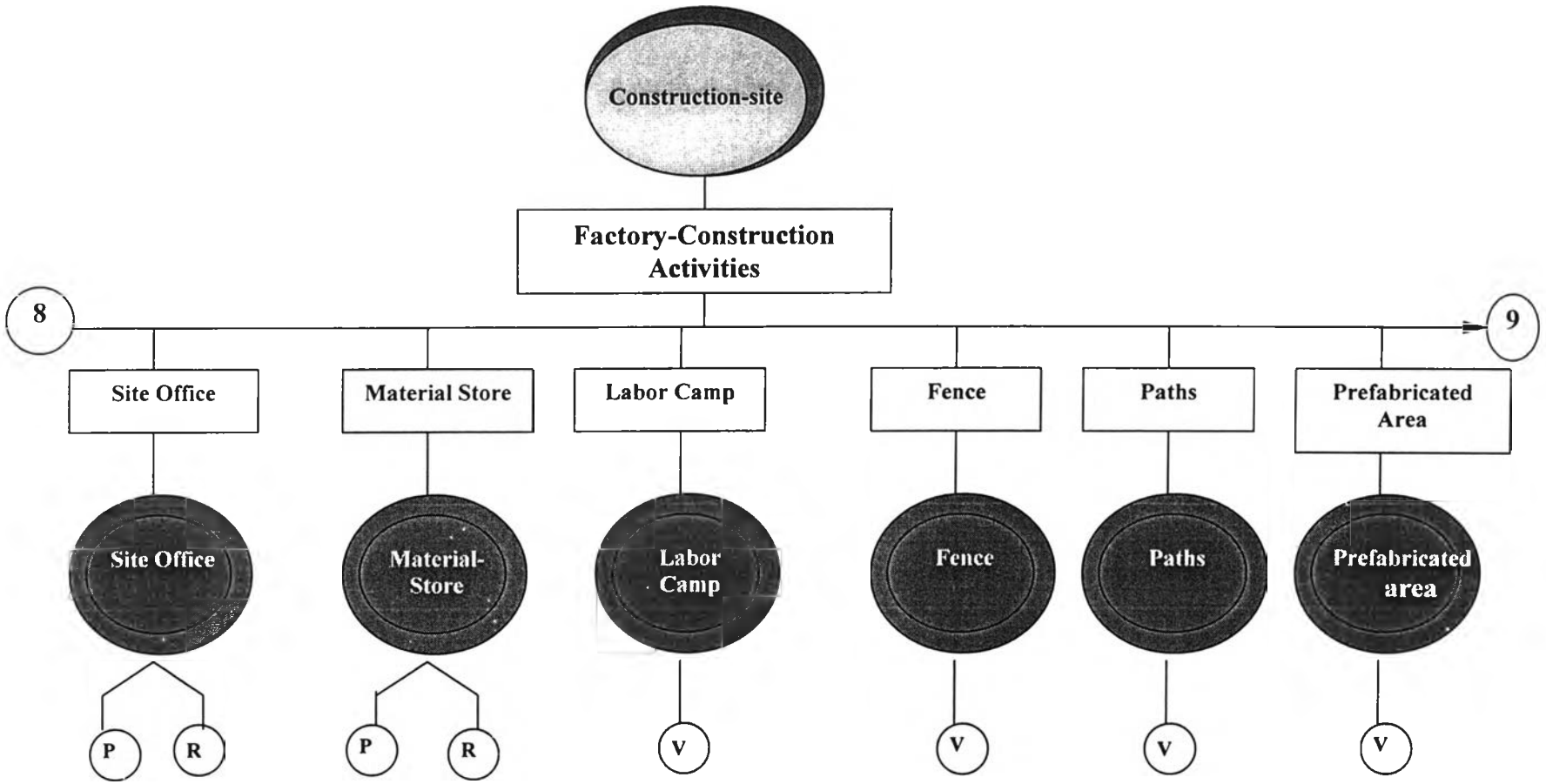


Figure A4-9: The controlling parameters of factory-construction activities (*continue*)

Appendix 5

Charts of
Properties and Details of Data for the Integrated System

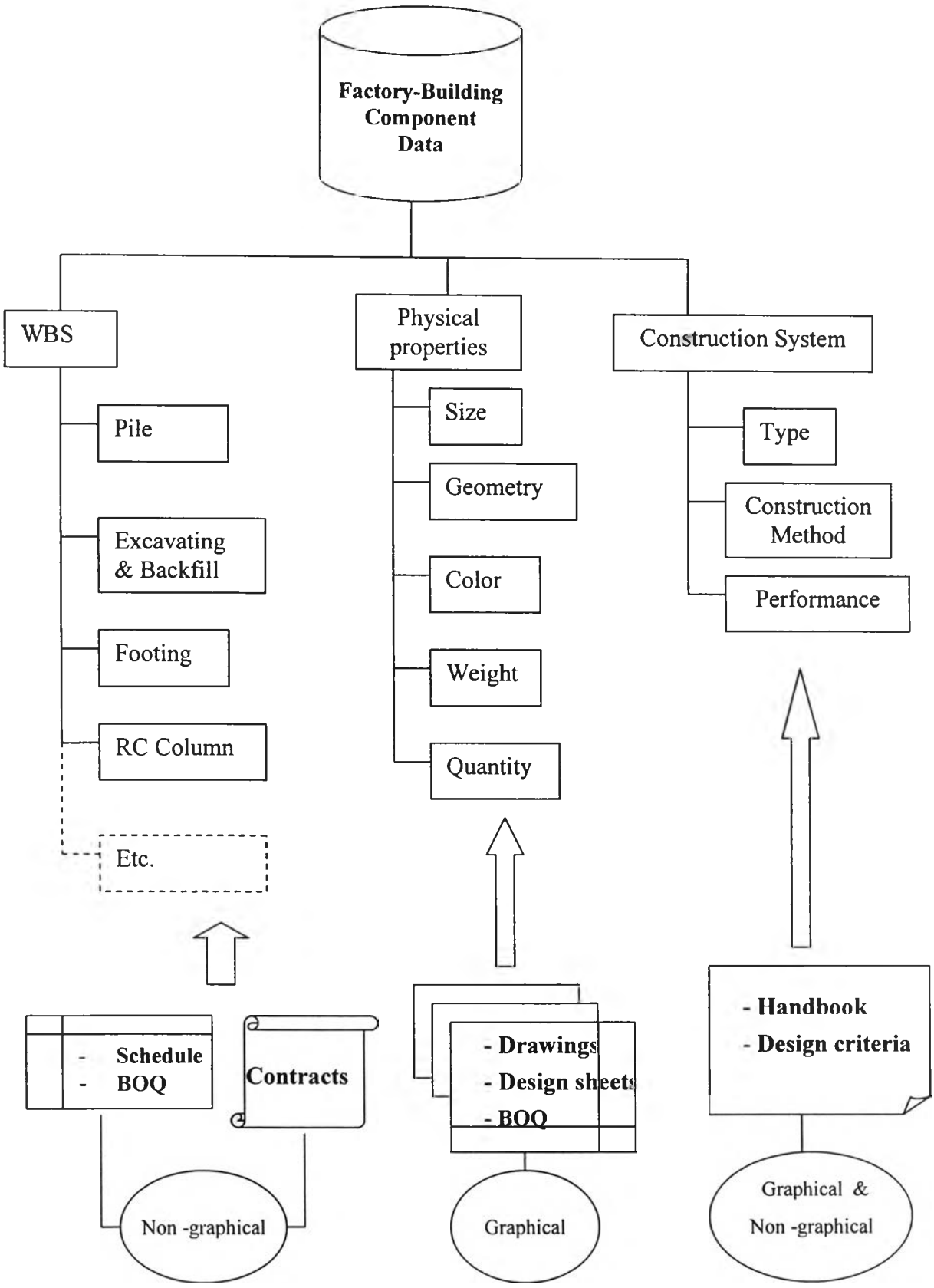


Figure A5-1: Properties and details of factory-building component data

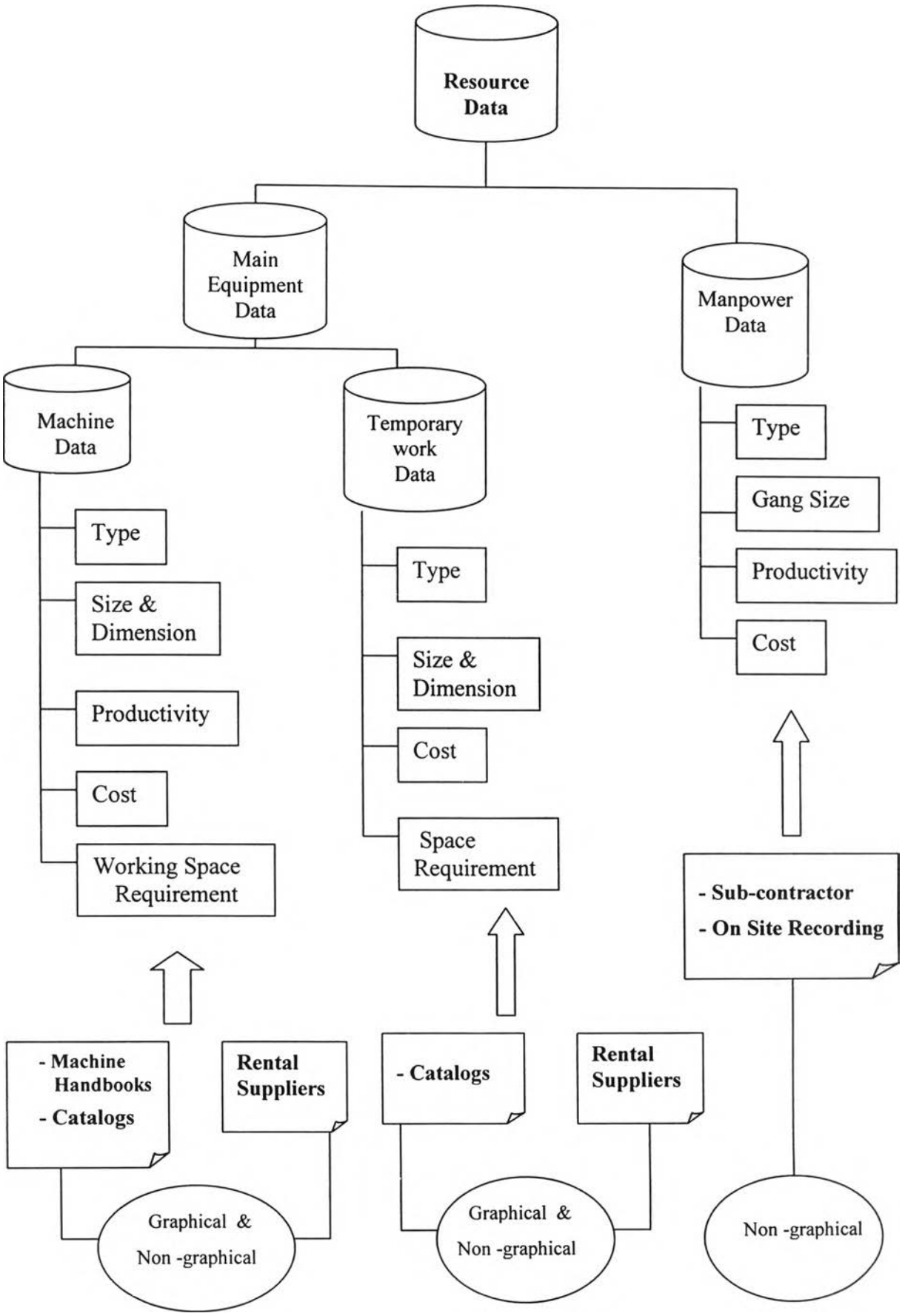


Figure A5-2: Properties and details of resource data

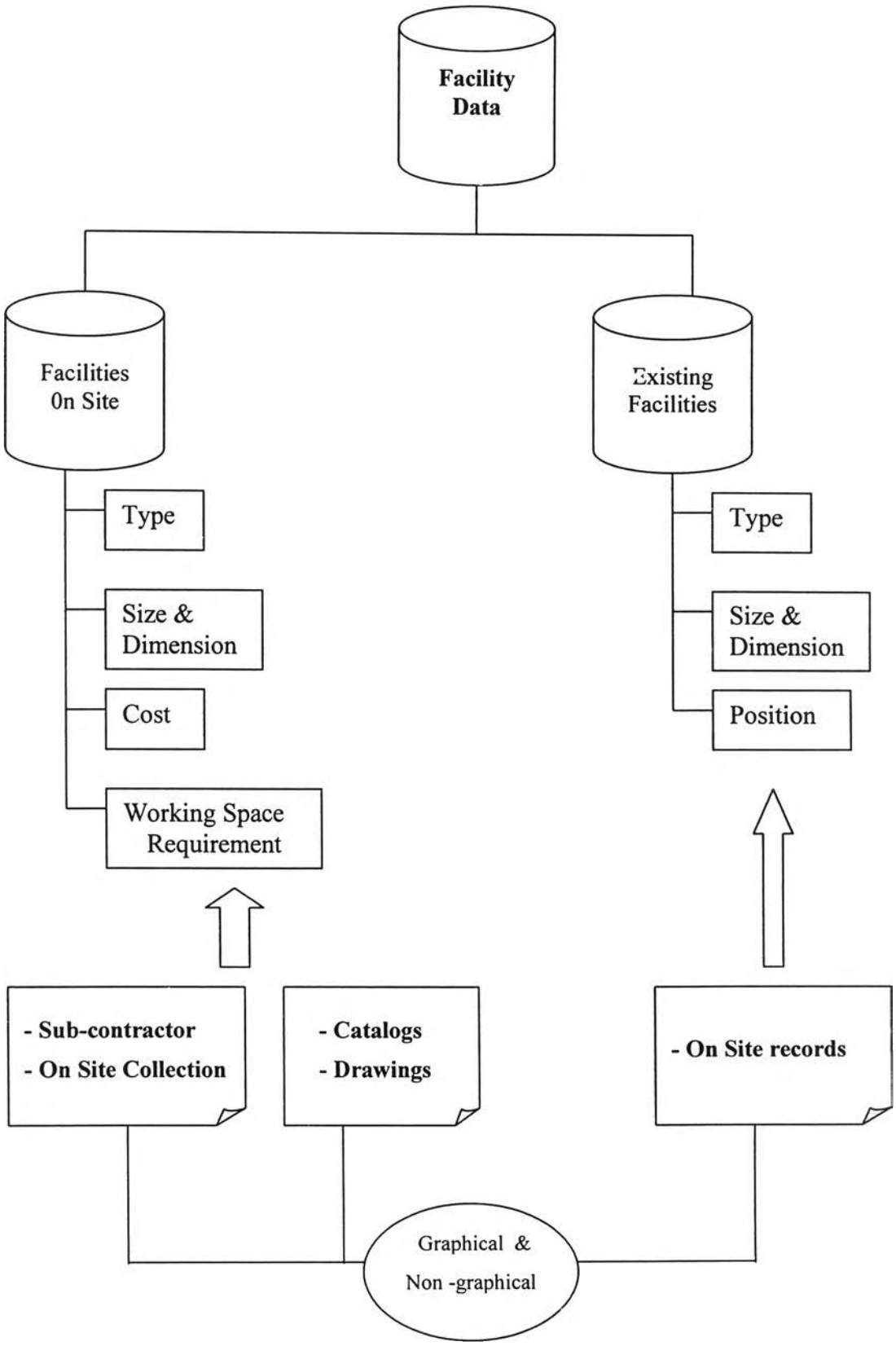


Figure A5-3: Properties and details of facility data

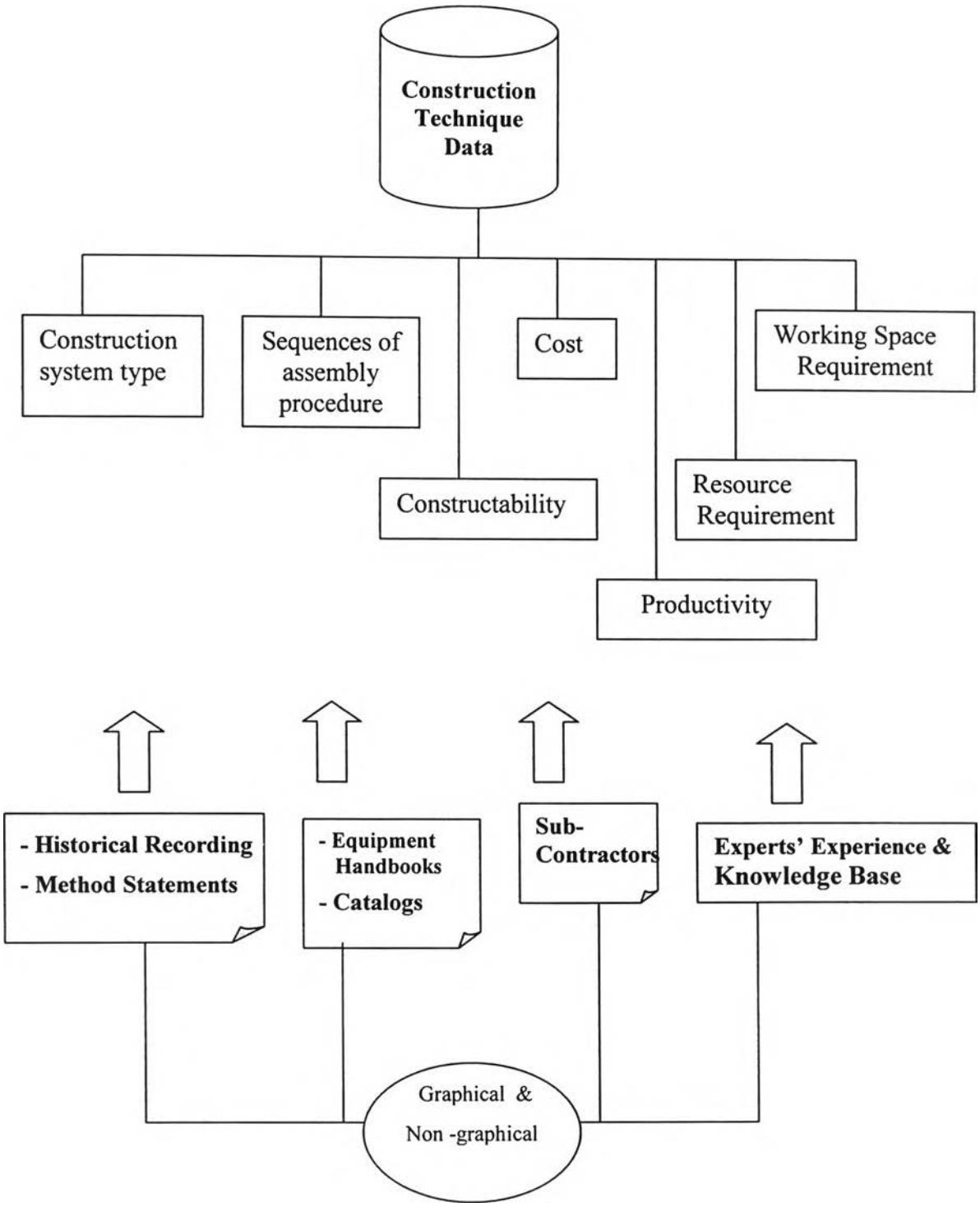


Figure A5-4: Properties and details of construction technique data

Appendix 6

Questionnaire Forms

QUESTIONNAIRES

General Information

Company's Name :_____

Your position: :_____

Your experience in construction :_____Years

Current of your Project Name : _____

Building Service Area : _____m^2

Construction Site Area :_____m^2

Planning Project Duration :_____months

PART A
Questionnaire for Pre-screening

A1: Please choose 1 or more than 1 answers or fill in the blank

(1) Do you use computer for construction planning?

[ ] Yes
[ ] No

(2) If you answer "yes" in (1), What software do you use for scheduling ?

[ ] Excel
[ ] Microsoft Project
[ ] Primavera
[ ] Suretrack
[ ] Etc._____

(3) What documents do you use for construction planning ?

[ ] Drawing
[ ] BOQ
[ ] Contract document
[ ] Etc._____

(4) Who are in your planning team?

[ ] Project manager or Project engineer
[ ] Site engineer
[ ] Foreman or Craftsman Head
[ ] Sub-contractor
[ ] Supplier
[ ] Etc._____

(5) What planning technique do you apply for your construction planning?

[ ] Critical Path Method (CPM)
[ ] PERT
[ ] Simulation Technique
[ ] Etc._____

(6) What tool do you use for present or report your planning?

[ ] Barchart
[ ] Network Diagram
[ ] Simulation tools
[ ] Etc._____

(7) What problems are in planning process?

[ ] Lack of expert planning team
[ ] Lack of effective planning tools
[ ] Lack of data
[ ] Etc._____

PART B

Questionnaire for weighting the use and importance of planning tools

B1: What tools do you use for construction planning?

Please weight the degree of use and its importance as follows:

0 = Never use, not important or unknown : 1 = sometime use/low importance

2 = often use/ medium importance : 3 = usually use/ high importance

4 = always use/most importance

Planning Tools	Detail	Degree of use and importance	Remark
1) Computer		( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
2) Planning Software	1) Excel	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	2) Microsoft Project	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	3) Primavera	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	4) Suretrack	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	5) Simulation software	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	6) _____	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
3) Planning Document	1) Drawing	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	2) BOQ	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	3) Contract document	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	4) Etc._____	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
4) Planning Team	1) Project manager	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	2) Project engineer	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	3) Site engineer	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	4) Foreman	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	5) Craftsman head	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	6) Sub-contractor	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	7) Supplier	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	8) Etc._____	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
5) Planning Technique	1) CPM	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	2) PERT	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	3) Simulation Technique	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	Etc._____	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
6) Planning Data	1) Labor productivity	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	2) Machine productivity	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	3) Supplier productivity	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	4) Labor cost	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	5) Machine rent price	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	6) Sub-contract cost	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	
	7) Etc. _____	( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4	

PART C

Questionnaire for
Weighting problems of planning

C-1: What problems do you have during your planning?
Please weight the degree of problems as follows:

0 = Never occurred 1 = Sometime occurred
2 = Often occurred 3 = usually occurred

Planning problems	Degree of problems	Remark
1) Lack personals who have enough experiences for planning	( ) 0 ( ) 1 ( ) 2 ( ) 3	
2) Lack good planning team	( ) 0 ( ) 1 ( ) 2 ( ) 3	
3) Lack knowledge of planning technique as: 1) CPM technique 2) PERT technique 3) Simulation technique or etc.	 ( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 0 ( ) 1 ( ) 2 ( ) 3	
4) Lack effective planning tools such as: 1) Planning software	 ( ) 0 ( ) 1 ( ) 2 ( ) 3	
5) Lack personals who can use planning software Such as: 1) Microsoft Project 2) Primavera 3) Simulation software or etc.	 ( ) 0 ( ) 1 ( ) 2 ( ) 3	
6) Lack planning data such as: 1) Labor productivity 2) Machine productivity 3) Supplier productivity 4) Labor cost 5) Machine rent price 6) Sub-contract cost 7) Etc. _____	 ( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 0 ( ) 1 ( ) 2 ( ) 3	
7) Lack good communication among planning team	( ) 0 ( ) 1 ( ) 2 ( ) 3	
8) _____ _____ _____ _____	( ) 0 ( ) 1 ( ) 2 ( ) 3	

PART D

Questionnaire for
Weighting factors affect to planning errors

D1: What factors do affect to plan error? (Time and Cost error)

Please weighting the degree of factor affecting as follows:

0 = No affect 1 = less affect
2 = Medium affect 3 = more affect

Main Factors	Factors	Degree of affect	Remark
1) Mistake of management on construction site	1) Mistake of Construction method	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	2) Mistake of Construction sequence	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	3) Mistake of Type of machine use	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	4) Mistake of Quantity of machine use	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	5) Mistake of Quantity of labor use	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	6) _____	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	7) _____	( ) 0 ( ) 1 ( ) 2 ( ) 3	
2) Unseen conditions	1) Labor problems	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	2) Rainfall	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	3) Machine downtime	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	4) Accident	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	5) Suppliers delay	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	6) _____	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	7) _____	( ) 0 ( ) 1 ( ) 2 ( ) 3	
3)_____	_____	( ) 0 ( ) 1 ( ) 2 ( ) 3	
	_____		
	_____		

PART E

Questionnaire for
Screening the factors affecting the management mistakes at construction sites

E1: Do the following factors affecting to the management mistakes at construction sites?
Please select ( ) Yes ( ) No ( ) No comment

Major mistakes	Factors	Degree of effect
1) Construction method & sequence	1) **Not enough** experience	( ) Yes ( ) No ( ) No comment
	2) **Can not** plan construction sequence in 3 dimensions (Horizontal &Vertical)	( ) Yes ( ) No ( ) No comment
	3) **Bad communication** among construction team	( ) Yes ( ) No ( ) No comment
	4) _____	( ) Yes ( ) No ( ) No comment
2) Selecting type & quantity of construction machines	1) **Not enough** experience	( ) Yes ( ) No ( ) No comment
	2) **Not enough** machine information	( ) Yes ( ) No ( ) No comment
	3) **Not enough** productivity data	( ) Yes ( ) No ( ) No comment
	4) _____ _____	( ) Yes ( ) No ( ) No comment
	5) _____ _____	( ) Yes ( ) No ( ) No comment

Appendix 7

Examples of
Productivity Data Recorded from Construction Fields

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
203		16.00	18
204		16.00	23
205		16.00	20
	139	16.00	25
166		16.00	23
165		16.00	30
207		16.00	31
206		16.00	28
	208	16.00	24
	251	16.00	51
	253	16.00	30
119		16.00	17
118		16.00	20
117		16.00	15
153		16.00	16
154		16.00	9
155		16.00	13
156		16.00	12
157		16.00	19
158		16.00	17
159		16.00	25
160		16.00	35
161		16.00	30
162		16.00	30
181		16.00	26
180		16.00	29
179		16.00	28
178		16.00	32
177		16.00	29
176		16.00	32

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
219		16.00	33
220		16.00	27
221		16.00	31
222		16.00	35
223		16.00	27
224		16.00	29
225		16.00	21
215		16.00	25
214		16.00	35
213		16.00	27
211		16.00	35
258		16.00	40
257		16.00	30
256		16.00	25
259		16.00	30
260		16.00	25
1389		16.00	22
1375		16.00	22
1356		16.00	21
1342		16.00	15
1322		16.00	29
	1321	16.00	19
	1320	16.00	19
1341		16.00	15
1355		16.00	19
	1373	16.00	22
	1374	16.00	18
1388		16.00	17
1402		16.00	14
	1372	16.00	15

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
	1371	16.00	14
	1318	16.00	31
	885	16.00	40
	883	16.00	35
	884	16.00	25
924		16.00	20
	1158	16.00	30
1159		16.00	30
1157		16.00	30
1156		16.00	30
1093		16.00	30
1032		16.00	20
1155		16.00	35
1092		16.00	25
	74	16.00	38
	70	16.00	30
	67	16.00	30
65		16.00	36
68		16.00	30
71		16.00	28
99		16.00	40
98		16.00	30
97		16.00	24
96		16.00	30
	431	16.00	50
	519	16.00	25
	561	16.00	34
	653	16.00	55
	700	16.00	15
	787	16.00	30

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
	826	16.00	30
	906	16.00	37
	963	16.00	40
	1053	16.00	25
186		16.00	13
185		16.00	19
187		16.00	12
230		16.00	11
231		16.00	19
232		16.00	15
233		16.00	41
269		16.00	32
268		16.00	33
267		16.00	32
266		16.00	30
265		16.00	27
264		16.00	37
310		16.00	36
	566	14.50	60
	520	14.50	30
	473	14.50	45
	475	14.50	30
	1395	14.50	20
	1362	14.50	21
	1394	14.50	19
	1397	14.50	13
	1396	14.50	27
	1237	16.00	25
	1256	16.00	25
	1270	16.00	20

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
	1289	16.00	35
	1301	16.00	20
	1334	16.00	20
	18	16.00	22
	17	16.00	24
21		16.00	21
24		16.00	18
27		16.00	20
240			25
283			23
284			17
285			35
	339	13.50	25
338		15.00	23
337		15.00	17
336		15.00	35
320		16.00	25
321		16.00	26
322		16.00	25
323		15.00	30
324		15.00	31
325		15.00	37
326		15.00	17
327		15.00	16
370		15.00	17
369		15.00	22
368		15.00	23
367		15.00	45
366		15.00	10
356		16.00	15

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
354		16.00	29
352		16.00	28
353		16.00	33
351		16.00	15
350		16.00	35
349		16.00	30
394		16.00	26
395		16.00	27
396		16.00	24
397		16.00	30
398		16.00	26
399		16.00	34
295		15.00	30
296		15.00	25
141		15.00	30
301		16.00	25
302		16.00	20
303		16.00	25
304		16.00	20
	1013	16.00	19
	1012	16.00	40
	1059	16.00	24
	1075	16.00	26
	1122	16.00	24
	1143	16.00	22
	1196	16.00	22
	1222	16.00	21
	1232	16.00	22
	1248	16.00	13
	1265	16.00	28

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
	1281	16.00	26
1152		16.00	13
1089		16.00	12
1026		16.00	17
780		15.00	25
736		15.00	20
690		15.00	30
647		15.00	35
735		15.00	20
689		15.00	25
646		15.00	25
779		15.00	40
818		15.00	25
859		15.00	30
898		15.00	35
817		15.00	15
858		15.00	25
897		15.00	20
778		15.00	25
335		15.00	20
334		15.00	20
333		15.00	20
332		15.00	20
365		16.00	16
364		16.00	21
363		16.00	17
362		16.00	24
361		16.00	15
404		16.00	14
405		16.00	17

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
406		16.00	20
407		16.00	20
408		16.00	22
409		15.00	15
400		16.00	25
	360	14.50	39
	1445	14.50	28
	494	14.50	23
	1443	14.50	26
449		16.00	24
403		16.00	27
	492	14.50	25
	493	14.50	24
	358	14.50	25
	359	14.50	24
305		16.00	25
345		16.00	25
346		16.00	25
347		16.00	25
348		16.00	25
344		16.00	35
343		16.00	30
342		16.00	30
	1296	16.00	14
	1317	16.00	45
	1316	16.00	15
	1295	16.00	20
	1280	16.00	19
	1264	15.00	15
	1247	15.00	15

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
	1231	15.00	18
	1221	15.00	15
	1195	15.00	18
	1142	15.00	23
	1074	15.00	30
981		16.00	31
922		16.00	21
881		16.00	23
844		16.00	18
803		16.00	14
802		16.00	15
843		16.00	20
880		16.00	20
921		16.00	10
734		15.00	25
688		15.00	30
645		15.00	30
644		15.00	30
687		15.00	25
733		15.00	30
777		15.00	50
816		15.00	20
857		15.00	30
896		15.00	15
	1111	13.50	20
	1190	13.50	20
372		15.00	18
371		15.00	20
376		15.00	12
377		15.00	26

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
378		15.00	12
379		15.00	12
380		15.00	23
	382	13.50	16
	384	16.00	15
	385	13.50	24
	383	13.50	15
	425	13.50	21
457		15.00	25
458		15.00	17
456		15.00	21
455		15.00	22
454		16.00	42
453		16.00	27
452		16.00	15
451		16.00	22
450		16.00	22
718		16.00	35
672		16.00	25
	627	15.00	35
	628	15.00	20
759		16.00	45
717		16.00	40
671		16.00	28
626		16.00	25
582		16.00	25
536		16.00	30
388		16.00	25
387		16.00	45
428		16.00	25

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
427		16.00	30
435		16.00	40
434		16.00	20
433		16.00	30
436		16.00	30
437		16.00	25
	1230	16.00	15
	1246	16.00	19
	1263	16.00	45
	1279	15.00	18
	1294	15.00	10
	1315	15.00	23
	1312	14.50	24
	1310	14.50	12
	1311	14.50	13
	1309	14.50	22
	1293	15.00	22
	1022	16.00	17
	1064	16.00	53
	1085	16.00	30
	1132	16.00	18
	1148	16.00	17
	1206	16.00	15
	1225	16.00	13
	1300	16.00	15
	1269	16.00	29
	1236	16.00	17
	1205	16.00	17
	1147	15.00	20
	1131	14.50	20

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
	1084	14.50	25
	1063	14.50	22
	1021	14.50	10
1447		15.00	35
	958	15.00	30
	959	15.00	25
	1002	15.00	30
	1049	15.00	30
	1110	15.00	25
1189		15.00	25
	1188	15.00	30
	1048	15.00	30
	1109	15.00	20
	1186	15.00	15
1187		15.00	30
462		15.00	16
461		15.00	25
460		15.00	26
463		15.00	12
464		15.00	25
465		15.00	15
466		15.00	16
467		15.00	18
468		15.00	17
469		15.00	29
429		13.50	22
430		13.50	24
514		15.00	18
547		15.00	13
546		15.00	20

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
545		15.00	29
544		15.00	21
543		15.00	19
542		16.00	25
	355	15.00	32
	1444	15.00	20
446		16.00	26
	489	154.00	25
	1442	16.00	26
535		16.00	28
581		16.00	22
625		16.00	25
670		16.00	31
716		16.00	19
758		16.00	47
476		16.00	15
523		16.00	25
522		16.00	35
521		16.00	30
	1072	16.00	25
	1056	16.00	25
	1009	16.00	25
	1008	16.00	45
	1055	14.50	25
	1071	14.50	30
	1118	14.50	35
	1139	14.50	25
	1192	14.50	35
	1218	16.00	35
878		16.00	18

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
919		16.00	14
978		16.00	24
	1020	14.50	23
	1062	14.50	19
	1083	14.50	18
977		16.00	20
918		16.00	20
877		16.00	22
840		16.00	26
	1182	15.00	30
	1180	15.00	25
	1178	15.00	40
	1176	15.00	50
	1104	15.00	70
	1105	15.00	30
	1106	15.00	40
	1107	15.00	30
	1108	15.00	20
	1109	15.00	40
	1043	15.00	25
	1044	15.00	20
	1045	15.00	35
513		15.00	22
512		15.00	29
511		15.00	21
510		15.00	25
509		15.00	46
508		15.00	18
541		16.00	17
540		16.00	16

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
539		16.00	27
538		16.00	17
585		16.00	19
584		16.00	14
586		16.00	23
587		16.00	25
588		16.00	18
669		16.00	27
715		16.00	25
580		16.00	27
	624	14.50	33
	1440	14.50	28
	757	14.50	28
	1438	14.50	27
534		16.00	28
445		16.00	20
444		16.00	24
443		16.00	22
442		16.00	30
565		16.00	25
564		16.00	30
524		16.00	40
525		16.00	25
526		16.00	25
527		16.00	35
528		16.00	25
574		16.00	35
	1228	16.00	30
	1244	15.00	30
	1261	15.00	20

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
	1277	15.00	30
	1292	15.00	30
	1314	15.00	25
	1313	15.00	35
	1291	15.00	30
799		16.00	15
976		16.00	17
917		16.00	15
876		16.00	23
839		16.00	17
798		16.00	32
1018		16.00	20
1081		16.00	23
1128		16.00	21
1202		16.00	26
1254		16.00	17
	1046	15.00	25
1161		15.00	30
1163		15.00	21
1165		15.00	21
1167		15.00	18
1173		15.00	21
507		15.00	15
506		15.00	17
505		15.00	15
548		15.00	12
549		15.00	22
550		15.00	17
551		15.00	22
552		15.00	21

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
553		15.00	24
554		15.00	14
555		15.00	33
556		15.00	25
557		15.00	32
590		15.00	21
591		15.00	19
592		16.00	15
593		16.00	20
639		16.00	20
1462		16.00	21
1461		15.00	25
1460		15.00	21
441		16.00	30
484		16.00	26
485		16.00	29
486		16.00	27
487		16.00	26
488		16.00	26
532		16.00	34
533		16.00	24
531		16.00	21
530		16.00	33
529		16.00	31
575		16.00	25
576		16.00	23
573		16.00	31
572		16.00	25
571		16.00	35
570		16.00	30

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
569		16.00	25
568		16.00	35
567		16.00	25
	1276	15.00	25
	1260	15.00	25
	1243	15.00	25
	1227	15.00	30
	1217	15.00	35
	1191	15.00	30
	1138	15.00	30
	1117	15.00	25
	1070	15.00	30
	1333	15.00	28
	1299	15.00	26
	1288	15.00	15
	1268	15.00	27
	1255	15.00	17
	1235	15.00	28
	1224	15.00	11
	1204	15.00	27
	1146	15.00	17
	1130	15.00	16
1171		15.00	30
1175		15.00	30
	1174	15.00	30
	1172	15.00	20
1169		15.00	60
	1170	15.00	30
	1168	15.00	25
	1166	15.00	30

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
	1164	15.00	50
	1162	15.00	25
	1160	15.00	35
1459		15.00	18
1458		15.00	10
1457		15.00	16
1456		15.00	17
1455		15.00	23
895		15.00	13
894		15.00	25
893		15.00	15
892		15.00	15
891		15.00	18
890		15.00	18
889		15.00	25
850		15.00	17
851		15.00	7
577		16.00	45
578		16.00	20
579		16.00	27
621		16.00	25
622		16.00	15
623		16.00	20
620		16.00	30
619		16.00	20
665		16.00	20
613		16.00	40
612		16.00	30
611		16.00	35
614		16.00	20

PILE DATA

PILE NO.		LENGTH (M.)	TIME (MIN.)
I 26	I 30		
615		16.00	30
616		16.00	30
617		16.00	25
618		16.00	35
	1007	15.00	30
	1054	15.00	25
	1005	15.00	35
	1215	14.50	25
1116		16.00	25
	1130	14.50	30
	1068	14.50	40
	1298	15.00	28
	1267	15.00	20
	1234	15.00	18
	1203	15.00	21
	1145	15.00	18
	1129	15.00	35
	1082	15.00	21
	1061	15.00	31
	1019	15.00	23
	1101	15.00	25
	1102	15.00	30
	1103	15.00	55

Appendix 8

Flow Chart Used for Programming Construction Activities

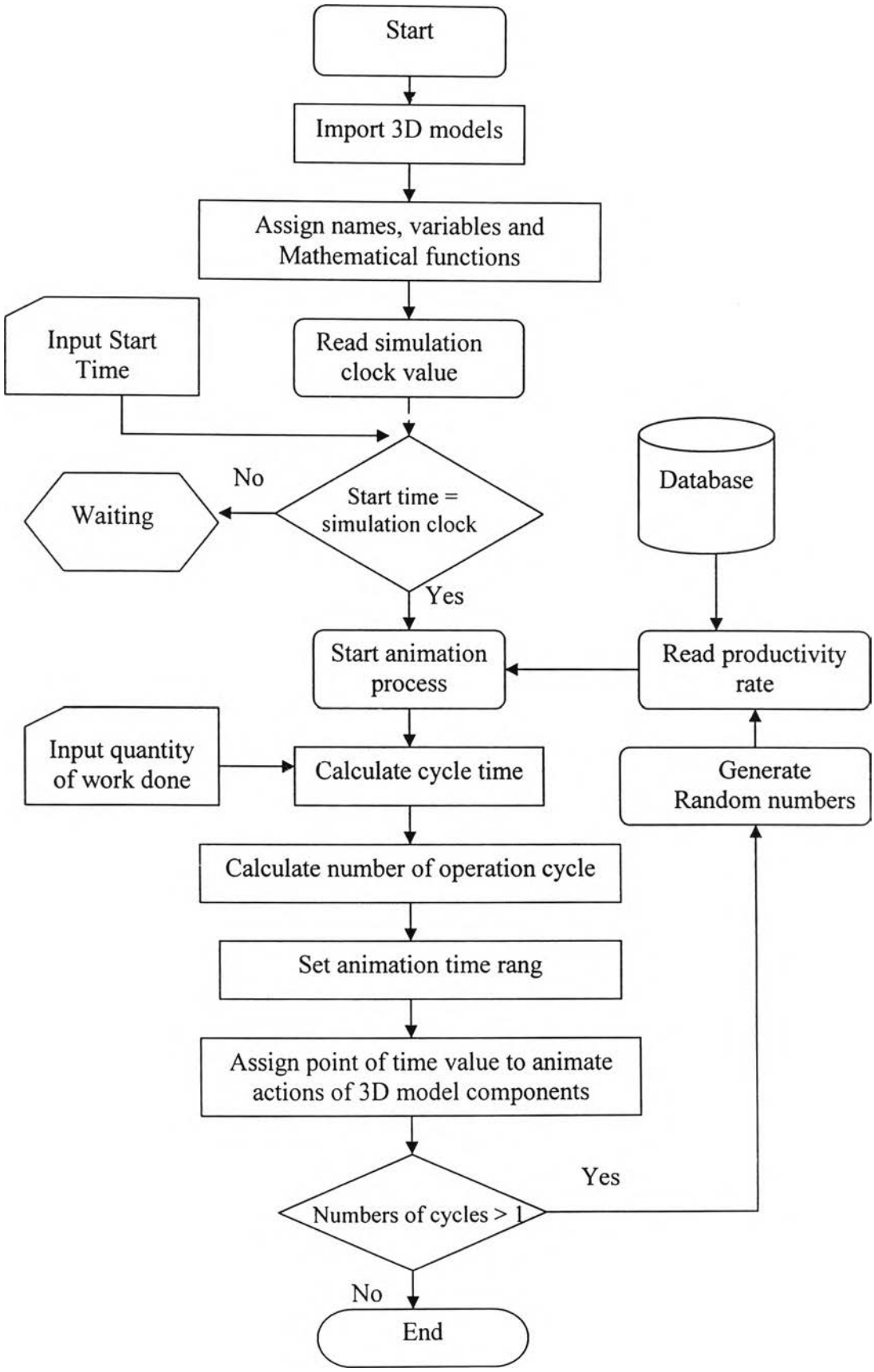


Figure A8-1: Flow Chart for programming the factory-construction activities by Visualizer Scripts

Appendix 9

Examples of System Input & Output Floater Generated by Visualzer Scripts

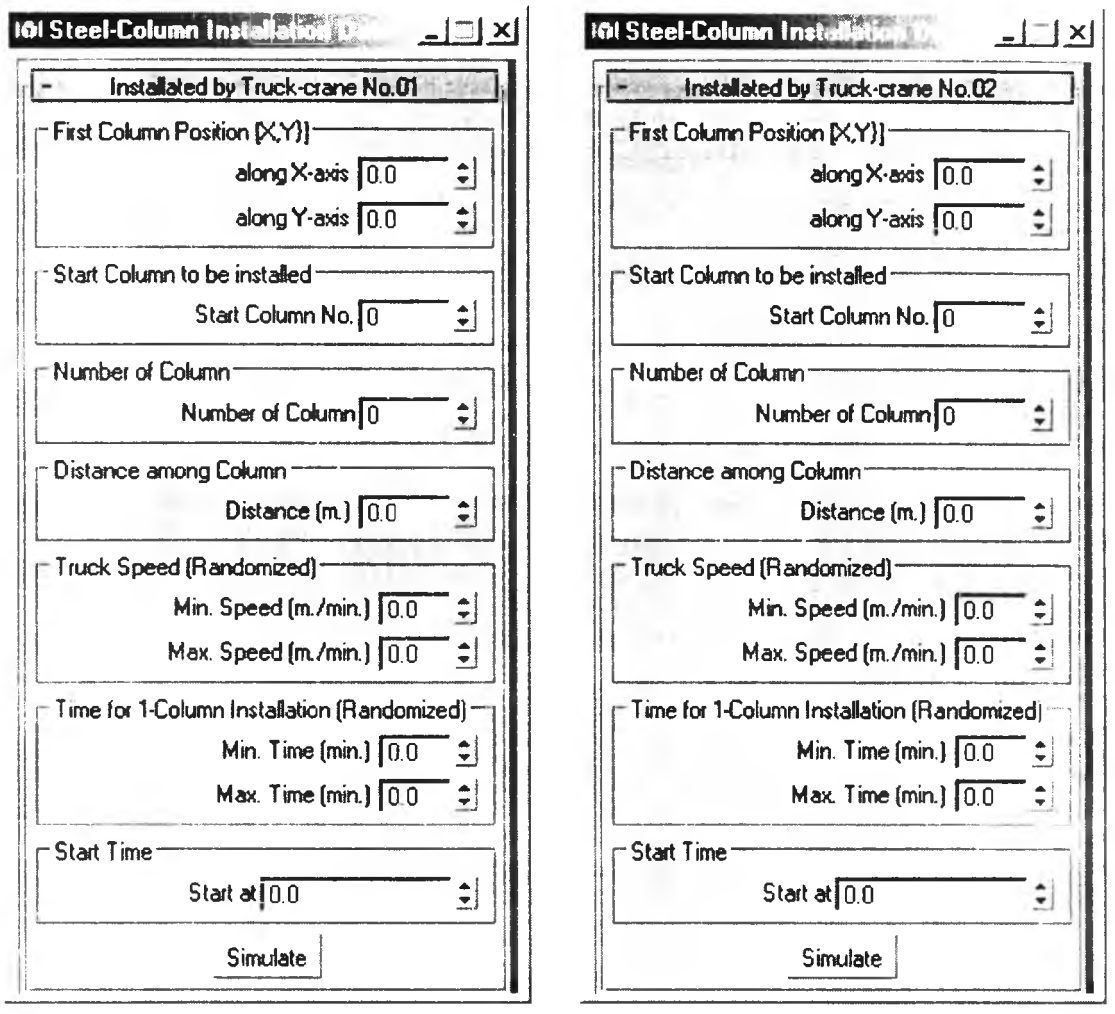


Figure A9-1: Input windows used to simulate steel-column installation by two truck-cranes.

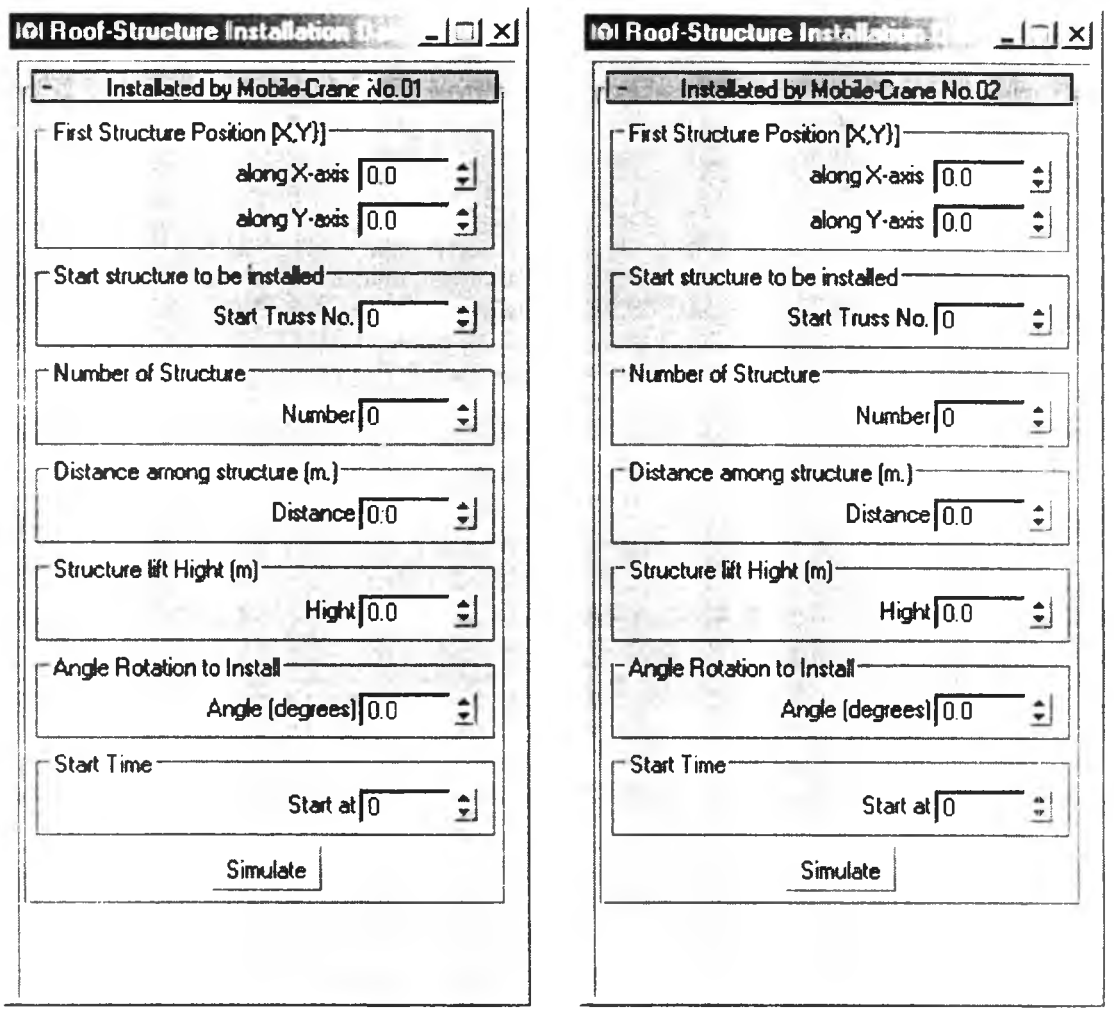


Figure A9-2: Input windows used to simulate roof-truss installation by one mobile-crane.

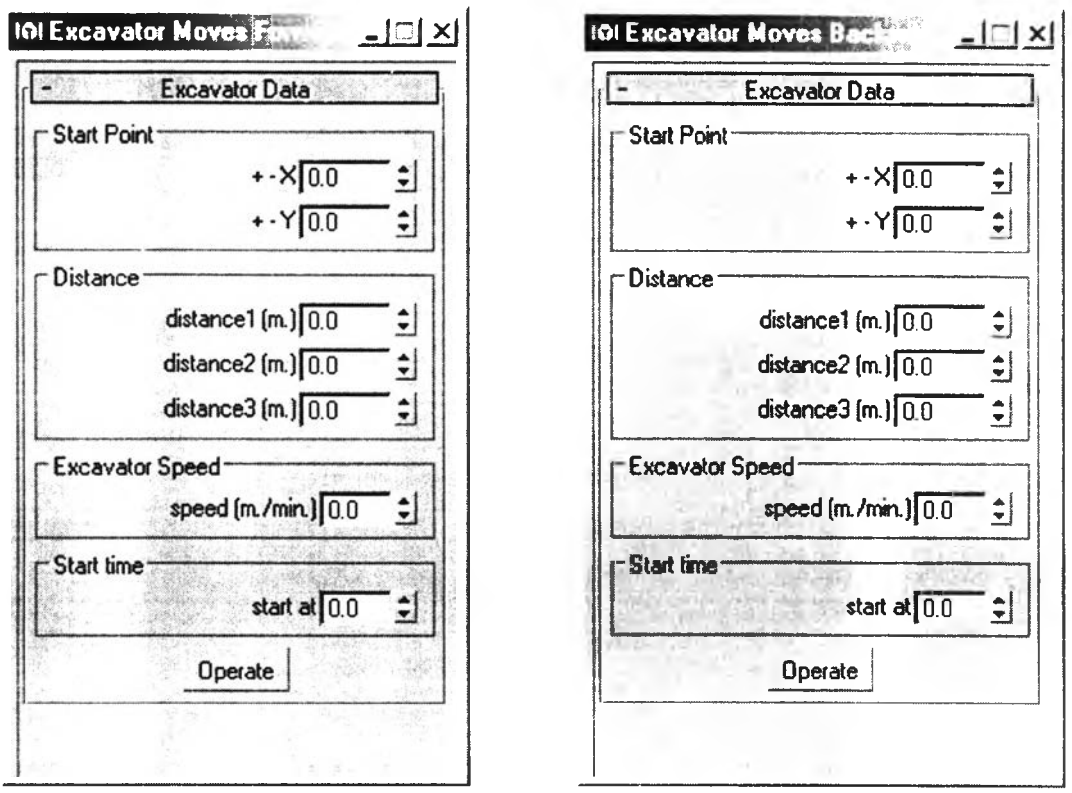


Figure A9-3: Input windows used to simulate roof-truss carrying by an excavator

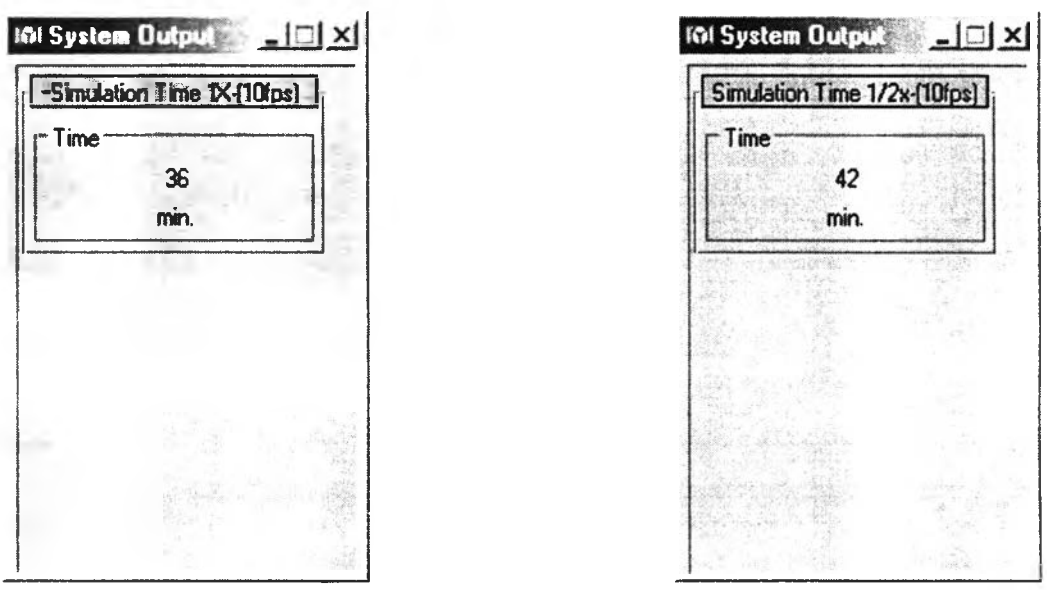


Figure A9-4: Output windows of simulation time

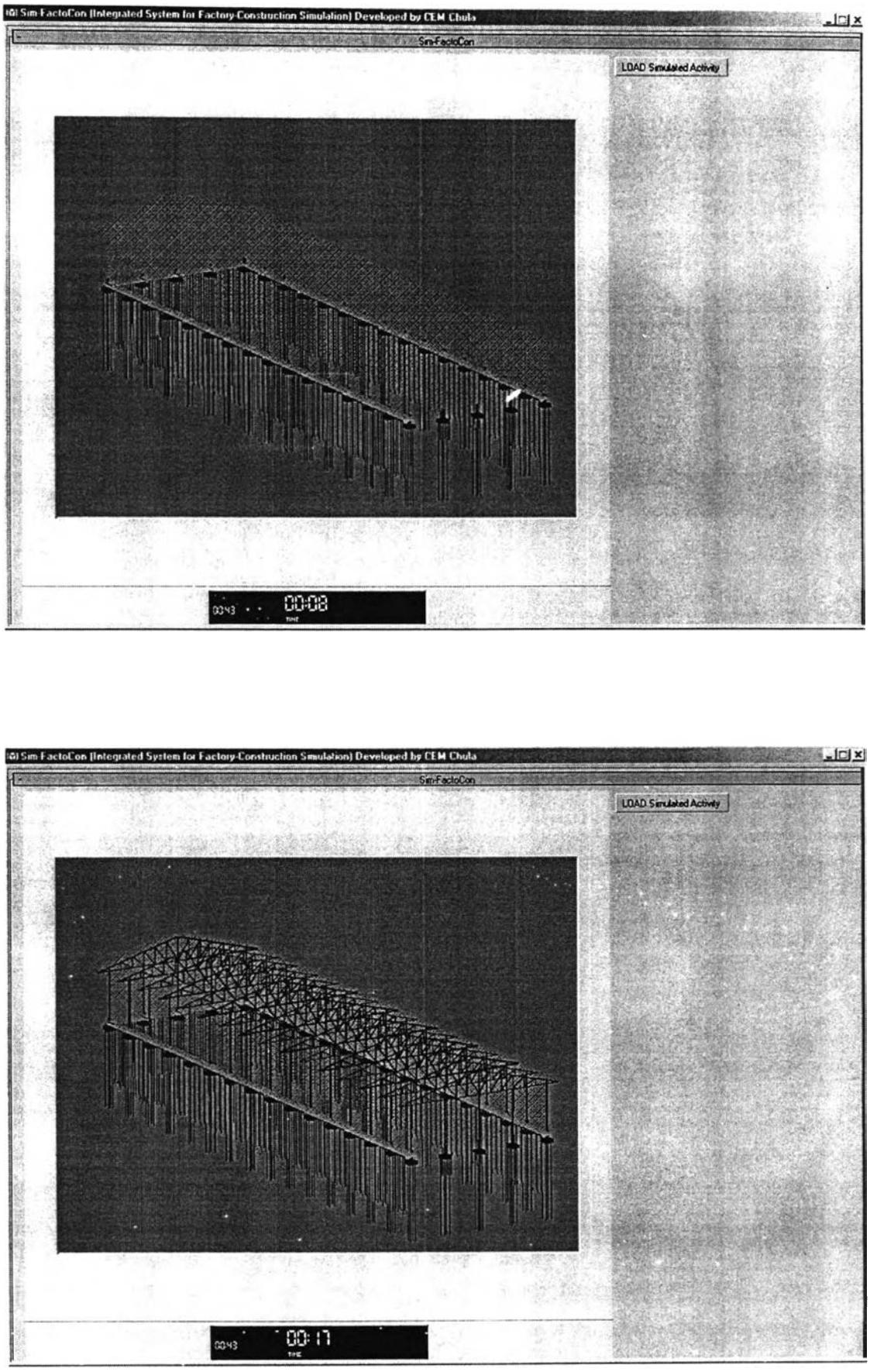


Figure A9-5: Windows for visualizing factory-building construction processes and time

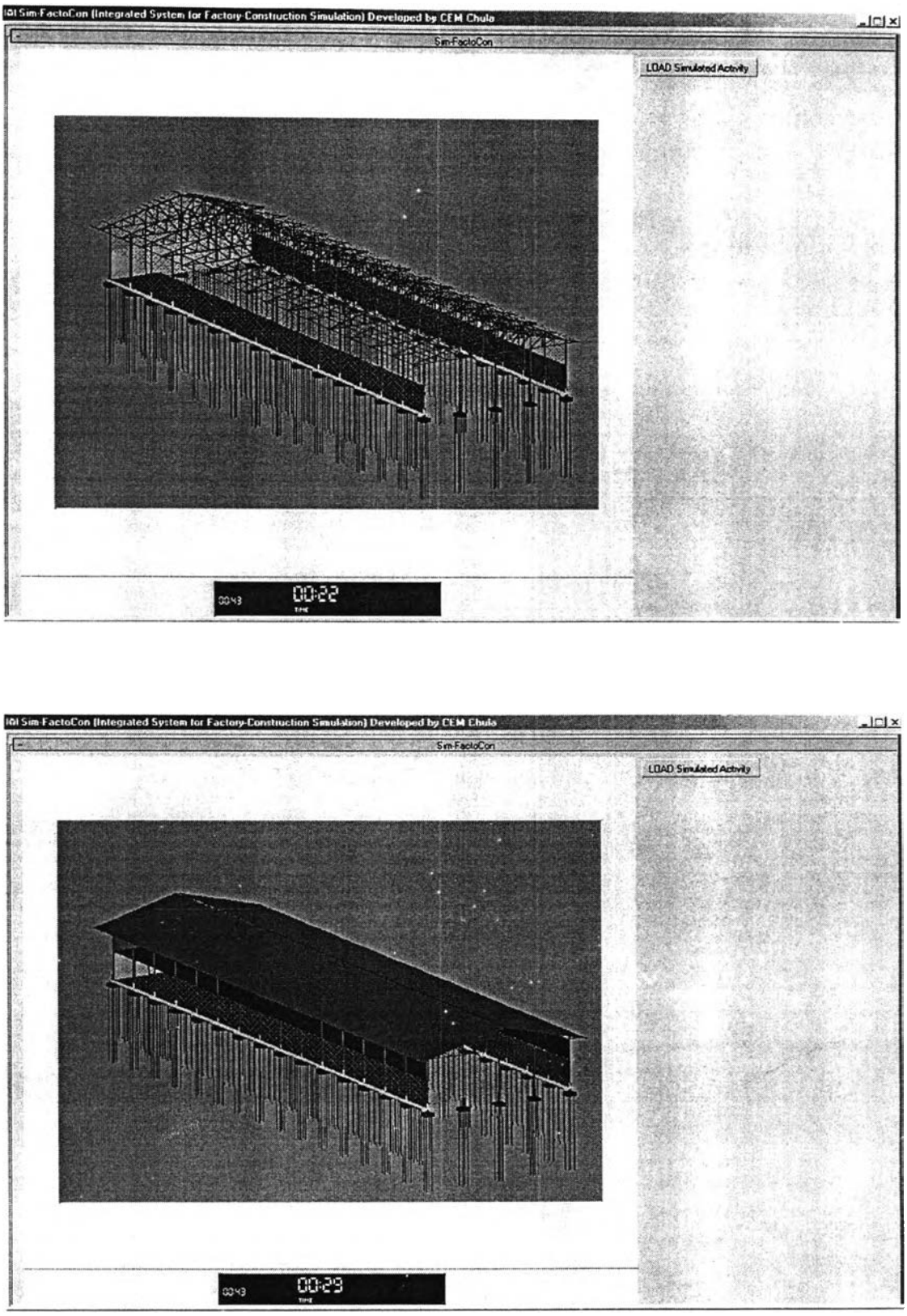


Figure A9-6: Windows for visualizing factory-building construction processes and time (*continue*)

Appendix 10

Examples of Source Codes of the Development of the Integrated System

```
------------------------------------------------------------------
--                        Code
--     for Simulating Steel Column Installation
--           by Using Truck-crane No.01
--              created by
--             Noppadon Jokkaw
------------------------------------------------------------------
------------------------------------------------------------------
-- Assigning the variables
------------------------------------------------------------------
utility stcolx "Installated by Truck-crane No.01"
(
group "First Column Position [X,Y}]"
(
spinner xpos "                    along X-axis " range:[-
100,100,0] \
type:#float scale:0.2 fieldwidth:50
spinner ypos "                    along Y-axis "  range:[-
100,100,0] \
type:#float scale:0.2 fieldwidth:50
)

group "Start Column to be installed"
(
spinner scoln "Start Column No." range:[0,100,0] \
type:#integer fieldwidth:50
)

group "Number of Column"
(
spinner Ncol "Number of Column" range:[0,100,0] \
type:#integer fieldwidth:50
)

group "Distance among Column"
(
spinner codis "                       Distance (m.) "
range:[0,100,0] \
type:#float scale:0.2 fieldwidth:50
)

group "Truck Speed (Randomized)"
(
spinner excsp1 "          Min. Speed (m./min.) " range:[0,10,0] \
type:#float scale:0.1 fieldwidth:40
spinner excsp2 "          Max. Speed (m./min.) " range:[0,30,0] \
type:#float scale:0.1 fieldwidth:40
)

group "Time for 1-Column Installation (Randomized)"
(
spinner instime1 "          Min. Time (min.) " range:[0,30,0] \
type:#float scale:0.1 fieldwidth:40
spinner instime2 "          Max. Time (min.) " range:[0,60,0] \
type:#float scale:0.1 fieldwidth:40
)
```

```
group "Start Time"
(
spinner start "Start at" range:[0,100000,0] \
type:#float scale:0.1 fieldwidth:100
)
------------------------------------------------------------------------
---
-- Design button
-------------------------------
button co_simx "Simulate"

on co_simx pressed do
(
-------------------------------
-- Assigned Variable Value
-------------------------------
sc01 = xpos.value
sc02 = ypos.value
sc03 = Ncol.value
sc04 = codis.value
sc05 = excsp1.value
sc06 = excsp2.value
sc07 = instime1.value
sc08 = instime2.value
sc09 = scoln.value
brt01= random 1 3
brt02= random 1 3
brt03= random 1 3
brt04= random 1 3
brt05= random 1 3
brt06= random 1 3
brt07= random 1 3

-------------------------------------------
-------------------------------------------
--Simulation time unit (frame per min.)-----
f = 10
-------------------------------------------
-------------------------------------------
--Function Operation-----------------------
-------------------------------------------
s=start.value
--(att = average travel time)
rds = random sc05 sc06
inst= random sc07 sc08
att = sc04/rds
nco = sc03
--total time for body move per 1 cycle
n = (brt01+brt02+brt03+brt04+brt05+brt06+brt07+inst+att)*f
------------------------------------------------------------------
ttt = nco*n
ni = s+ttt
--acommulated time frame
-------------------------------
x1=0
x2 = sc09
```

```
x3=0
------------------------------
for i in s to ni by n do
(
tf01 = (i+brt01*f)
tf02 = (tf01+brt02*f)
tf03 = (tf02+brt03*f)
tf04 = (tf03+inst*f)
tf05 = (tf04+brt04*f)
tf06 = (tf05+brt05*f)
tf07 = (tf06+brt06*f)
tf08 = (tf07+brt07*f)
tf09 = (tf08+att*f)
-------------------------------------------
--Create Time Frame-------------------------
-------------------------------------------
sc021=sc02+sc04
x3=x3+1
if x3<=nco then
(
AnimationRange = Interval 0 ni
set animate on
   set time i
   rotate $boomhiap02 0 x_axis

set animate on
   set time tf01
   rotate $boomhiap02 30 x_axis

set animate on
   set time tf02
   rotate $Rhiap02 0 z_axis

set animate on
   set time tf03
   rotate $Rhiap02 90 z_axis

set animate on
   set time tf04
   rotate $Rhiap02 0 z_axis

set animate on
   set time tf05
   rotate $Rhiap02 -90 z_axis

set animate on
   set time tf06
   rotate $boomhiap02 0 x_axis

set animate on
   set time tf07
   rotate $boomhiap02 -30 x_axis

a = bezier_position ()
$hiapwh02.position.controller = a
```

```
k = addNewKey a tf08
k.value = [sc01+4.5,sc02,1.7]
k.outTangentType = #linear

k = addNewKey a tf09
k.value = [sc01+4.5,sc021,1.7]
k.inTangentType = #linear
k.outTangentType = #step
)--end if of machine move
else
endif


-----------------------------------------------
-----------------------------------------------
--Excel Chart Present Accumulate Time
-----------------------------------------------
x1=x1+1

if x1!=nco then
print x1
else
(print tf09
ExcelApp = CreateOLEObject "excel.application"
ExcelApp.Visible = true
ExcelApp.Workbooks.Add()

(ExcelApp.Range "a1").Value = (tf01-s)/f
(ExcelApp.Range "a2").Value = (tf02-s)/f
(ExcelApp.Range "a3").Value = (tf03-s)/f
(ExcelApp.Range "a4").Value = (tf04-s)/f
(ExcelApp.Range "a5").Value = (tf05-s)/f
(ExcelApp.Range "a6").Value = (tf06-s)/f
(ExcelApp.Range "a7").Value = (tf07-s)/f
(ExcelApp.Range "a8").Value = (tf08-s)/f
(ExcelApp.Range "a9").Value = (tf09-s)/f

(ExcelApp.Range "a1:a9").Select()
ExcelChart = ExcelApp.Charts.Add()
)--end else of excel
-----------------------------------------
-----------------------------------------
--Columns are moved to the positions
-----------------------------------------


if x1<=nco then
(
-----------------------------------------


if x2!=32 then
if x2!=31 then
if x2!=30 then
if x2!=29 then
if x2!=28 then
```

```
if x2!=27 then
if x2!=26 then
if x2!=25 then
if x2!=24 then
if x2!=23 then
if x2!=22 then
if x2!=21 then
if x2!=20 then
if x2!=19 then
if x2!=18 then
if x2!=17 then

if x2!=16 then
if x2!=15 then
if x2!=14 then
if x2!=13 then
if x2!=12 then
if x2!=11 then
if x2!=10 then
if x2!=9 then
if x2!=8 then
if x2!=7 then
if x2!=6 then
if x2!=5 then
if x2!=4 then
   if x2!=3 then
      if x2!=2 then
         if x2!=1 then
         enif
         else --for col001
         (set animate on
          set time tf02
          rotate $col001 0 x_axis

          set animate on
          set time tf03
          rotate $col001 90 x_axis

          b = bezier_position ()
          $col001.position.controller = b

          l = addNewKey b tf02
          l.value = [14,sc02,0]
          l.outTangentType = #linear

          l = addNewKey b tf03
          l.value = [sc01,sc02,4.5]
          l.outTangentType = #linear
          )

      else --for col002
      (set animate on
          set time tf02
          rotate $col002 0 x_axis

          set animate on
```

```
            set time tf03
            rotate $col002 90 x_axis

            b = bezier_position ()
            $col002.position.controller = b

            l = addNewKey b tf02
            l.value = [14,sc02,0]
            l.outTangentType = #linear

            l = addNewKey b tf03
            l.value = [sc01,sc02,4.5]
            l.outTangentType = #linear
            )

    else --for col003
        (set animate on
         set time tf02
         rotate $col003 0 x_axis

         set animate on
         set time tf03
         rotate $col003 90 x_axis

         b = bezier_position ()
         $col003.position.controller = b

         l = addNewKey b tf02
         l.value = [14,sc02,0]
         l.outTangentType = #linear

         l = addNewKey b tf03
         l.value = [sc01,sc02,4.5]
         l.outTangentType = #linear
         )

else --for col004
  (set animate on
   set time tf02
   rotate $col004 0 x_axis

   set animate on
   set time tf03
   rotate $col004 90 x_axis

   b = bezier_position ()
   $col004.position.controller = b

   l = addNewKey b tf02
   l.value = [14,sc02,0]
   l.outTangentType = #linear

   l = addNewKey b tf03
   l.value = [sc01,sc02,4.5]
   l.outTangentType = #linear
   )
```

```
else --for col005
 (set animate on
  set time tf02
  rotate $col005 0 x_axis

  set animate on
  set time tf03
  rotate $col005 90 x_axis

  b = bezier_position ()
  $col005.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col006
 (set animate on
  set time tf02
  rotate $col006 0 x_axis

  set animate on
  set time tf03
  rotate $col006 90 x_axis

  b = bezier_position ()
  $col006.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col007
 (set animate on
  set time tf02
  rotate $col007 0 x_axis

  set animate on
  set time tf03
  rotate $col007 90 x_axis

  b = bezier_position ()
  $col007.position.controller = b

  l = addNewKey b tf02
```

```
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col008
   (set animate on
    set time tf02
    rotate $col008 0 x_axis

    set animate on
    set time tf03
    rotate $col008 90 x_axis

    b = bezier_position ()
    $col008.position.controller = b

    l = addNewKey b tf02
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col009
   (set animate on
    set time tf02
    rotate $col009 0 x_axis

    set animate on
    set time tf03
    rotate $col009 90 x_axis

    b = bezier_position ()
    $col009.position.controller = b

    l = addNewKey b tf02
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col010
   (set animate on
    set time tf02
    rotate $col010 0 x_axis

    set animate on
```

```
  set time tf03
  rotate $col010 90 x_axis

  b = bezier_position ()
  $col010.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col011
 (set animate on
  set time tf02
  rotate $col011 0 x_axis

  set animate on
  set time tf03
  rotate $col011 90 x_axis

  b = bezier_position ()
  $col011.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col012
 (set animate on
  set time tf02
  rotate $col012 0 x_axis

  set animate on
  set time tf03
  rotate $col012 90 x_axis

  b = bezier_position ()
  $col012.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )
```

```
else --for col013
 (set animate on
  set time tf02
  rotate $col013 0 x_axis

  set animate on
  set time tf03
  rotate $col013 90 x_axis

  b = bezier_position ()
  $col013.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col014
 (set animate on
  set time tf02
  rotate $col014 0 x_axis

  set animate on
  set time tf03
  rotate $col014 90 x_axis

  b = bezier_position ()
  $col014.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col015
 (set animate on
  set time tf02
  rotate $col015 0 x_axis

  set animate on
  set time tf03
  rotate $col015 90 x_axis

  b = bezier_position ()
  $col015.position.controller = b

  l = addNewKey b tf02
```

```
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col016
   (set animate on
    set time tf02
    rotate $col016 0 x_axis

    set animate on
    set time tf03
    rotate $col016 90 x_axis

    b = bezier_position ()
    $col016.position.controller = b

    l = addNewKey b tf02
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col017
   (set animate on
    set time tf02
    rotate $col017 0 x_axis

    set animate on
    set time tf03
    rotate $col017 90 x_axis

    b = bezier_position ()
    $col017.position.controller = b

    l = addNewKey b tf02
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col018
   (set animate on
    set time tf02
    rotate $col018 0 x_axis

    set animate on
```

```
    set time tf03
    rotate $col018 90 x_axis

    b = bezier_position ()
    $col018.position.controller = b

    l = addNewKey b tf02
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col019
   (set animate on
    set time tf02
    rotate $col019 0 x_axis

    set animate on
    set time tf03
    rotate $col019 90 x_axis

    b = bezier_position ()
    $col019.position.controller = b

    l = addNewKey b tf02
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col020
   (set animate on
    set time tf02
    rotate $col020 0 x_axis

    set animate on
    set time tf03
    rotate $col020 90 x_axis

    b = bezier_position ()
    $col020.position.controller = b

    l = addNewKey b tf02
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )
```

```
else --for col021
 (set animate on
  set time tf02
  rotate $col021 0 x_axis

  set animate on
  set time tf03
  rotate $col021 90 x_axis

  b = bezier_position ()
  $col021.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col022
 (set animate on
  set time tf02
  rotate $col022 0 x_axis

  set animate on
  set time tf03
  rotate $col022 90 x_axis

  b = bezier_position ()
  $col022.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col023
 (set animate on
  set time tf02
  rotate $col023 0 x_axis

  set animate on
  set time tf03
  rotate $col023 90 x_axis

  b = bezier_position ()
  $col023.position.controller = b

  l = addNewKey b tf02
```

```
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col024
   (set animate on
    set time tf02
    rotate $col024 0 x_axis

    set animate on
    set time tf03
    rotate $col024 90 x_axis

    b = bezier_position ()
    $col024.position.controller = b

    l = addNewKey b tf02
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col025
   (set animate on
    set time tf02
    rotate $col025 0 x_axis

    set animate on
    set time tf03
    rotate $col025 90 x_axis

    b = bezier_position ()
    $col025.position.controller = b

    l = addNewKey b tf02
    l.value = [14,sc02,0]
    l.outTangentType = #linear

    l = addNewKey b tf03
    l.value = [sc01,sc02,4.5]
    l.outTangentType = #linear
    )

  else --for col026
   (set animate on
    set time tf02
    rotate $col026 0 x_axis

    set animate on
```

```
  set time tf03
  rotate $col026 90 x_axis

  b = bezier_position ()
  $col026.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col027
 (set animate on
  set time tf02
  rotate $col027 0 x_axis

  set animate on
  set time tf03
  rotate $col027 90 x_axis

  b = bezier_position ()
  $col027.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col028
 (set animate on
  set time tf02
  rotate $col028 0 x_axis

  set animate on
  set time tf03
  rotate $col028 90 x_axis

  b = bezier_position ()
  $col028.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )
```

```
else --for col029
 (set animate on
  set time tf02
  rotate $col029 0 x_axis

  set animate on
  set time tf03
  rotate $col029 90 x_axis

  b = bezier_position ()
  $col029.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col030
 (set animate on
  set time tf02
  rotate $col030 0 x_axis

  set animate on
  set time tf03
  rotate $col030 90 x_axis

  b = bezier_position ()
  $col030.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col031
 (set animate on
  set time tf02
  rotate $col031 0 x_axis

  set animate on
  set time tf03
  rotate $col031 90 x_axis

  b = bezier_position ()
  $col031.position.controller = b

  l = addNewKey b tf02
```

```
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

else --for col032
 (set animate on
  set time tf02
  rotate $col032 0 x_axis

  set animate on
  set time tf03
  rotate $col032 90 x_axis

  b = bezier_position ()
  $col032.position.controller = b

  l = addNewKey b tf02
  l.value = [14,sc02,0]
  l.outTangentType = #linear

  l = addNewKey b tf03
  l.value = [sc01,sc02,4.5]
  l.outTangentType = #linear
  )

)--end if for move col.
-----------------------------------------------
else
endif
-----------------------------------------------
sc02=sc02+sc04
sc021=sc021+sc04
x2 = x2-1

)--end for loop of accum. time frame
)--end on button
)--end utility

exc=newrolloutfloater "Steel-Column Installation Data" 250 200
addrollout stcolx exc
exc.size=[250,460]
```

```
-------------------------------------------------------------------
-- Sort Code of
-- Fatern of Excavator moving and rotating
-- by Noppadon j.
-------------------------------------------------------------------
-------------------------------------------------------------------
-- v = Excavator Speed (m/min.)

-----------------------------------
-- c = Operation Cost (Bahts/hr.)

-----------------------------------

Utility exmove "Excavator Data"
(
group "Start Point"
(spinner spx "+ - X" range:[-1000,1000,0] type:#float scale:0.2
fieldwidth:50
spinner spy "+ - Y"  range:[-1000,1000,0] type:#float scale:0.2
fieldwidth:50
)
group "Distance"
(
spinner dis1 "distance1 (m.)" range:[0,100,0] type:#float
scale:0.2 fieldwidth:50
spinner dis2 "distance2 (m.)"  range:[0,100,0] type:#float
scale:0.2 fieldwidth:50
spinner dis3 "distance3 (m.)"  range:[0,100,0] type:#float
scale:0.2 fieldwidth:50
)

group "Excavator Speed"
(
spinner x "speed (m./min.)" range:[0,100,0] type:#float scale:0.1
fieldwidth:40
)

group "Start time"
(
spinner st "start at" range:[0,100000,0] type:#float scale:0.1
fieldwidth:40
)

button move "Operate"
on move pressed do
(
   d1=dis1.value
   d2=dis2.value
   d3=dis3.value
   v=x.value
   mt=st.value
   sp1=spx.value
   sp2=spy.value
```

```
--Simulation time unit (frame per min.)
f = 10
---------------------------------


--Operation time
i=d1/v --dist1 move time
j=1 --rotate1 time
l=d2/v --dist2 move time
q=1 --rotate2 time
s=d3/v --dist3 move time

--total operation time
TT=i+j+l+q+s
-----------------------------------
--total operation cost

-------------------------------------

m=mt
n=(m+i*f)
o=(n+j*f)
p=(o+l*f)
r=(p+q*f)
t=(r+s*f)


AnimationRange = Interval 0 t
a = bezier_position ()
$wh02.position.controller = a

k = addNewKey a m
k.value = [sp1,sp2,0.5]
k.outTangentType = #linear

k = addNewKey a n
k.value = [sp1,sp2+d1,0.5]
k.inTangentType = #linear
k.outTangentType = #step

b = tcb_rotation ()
$wh02.rotation.controller = b
j = addNewKey b n
j.tension = 50
set animate on
   set time n
   rotate $wh02 0 z_axis


j = addNewKey b o
j.tension = 50
set animate on
   set time o
   rotate $wh02 90 z_axis

c = tcb_rotation ()
```

```
$body01.rotation.controller = c
j = addNewKey c n
j.tension = 50
set animate on
   set time n
   rotate $body01 0 z_axis

j = addNewKey c o
j.tension = 50
set animate on
   set time o
   rotate $body01 -90 z_axis

k = addNewKey a o
k.value = [sp1,sp2+d1,0.5]
k.outTangentType = #linear


k = addNewKey a p
k.value = [sp1+d2,sp2+d1,0.5]
k.inTangentType = #linear
k.outTangentType = #step

j = addNewKey b p
j.tension = 50
set animate on
   set time p
   rotate $wh02 0 z_axis

j = addNewKey b r
j.tension = 50
set animate on
   set time r
   rotate $wh02 -90 z_axis

j = addNewKey c p
j.tension = 50
set animate on
   set time p
   rotate $body01 0 z_axis

j = addNewKey c r
j.tension = 50
set animate on
   set time r
   rotate $body01 90 z_axis

k = addNewKey a r
k.value = [sp1+d2,sp2+d1,0.5]
k.outTangentType = #linear


k = addNewKey a t
k.value = [sp1+d2,sp2+d1-d3,0.5]
k.outTangentType = #linear
```

```
statx = sp1+d2
staty = sp2+d1-d3

print "Forward"
print statx
print staty
)
)


exc=newrolloutfloater "Excavator Moves Forward" 220 200
addrollout exmove exc
exc.size=[220,350]
```

```
------------------------------------------------------------------
--              Sort Code
--     for Simulating Roof Structure (Truss) Installation
--           by Using Mobile-crane No.01
--              created by
--            Noppadon Jokkaw
------------------------------------------------------------------
------------------------------------------------------------------
-- Assigning the variables
-----------------------------------------------
utility trussx "Installated by Mobile-Crane No.01"
(
group "First Structure Position [X,Y)]"
(
spinner xspos "                    along X-axis " range:[-
100,100,0] \
type:#float scale:0.2 fieldwidth:50
spinner yspos "                    along Y-axis " range:[-
100,100,0] \
type:#float scale:0.2 fieldwidth:50
)

group "Start structure to be installed"
(
spinner struss "Start Truss No." range:[0,100,0] \
type:#integer fieldwidth:50
)

group "Number of Structure"
(
spinner notruss "Number" range:[0,100,0] \
type:#integer fieldwidth:50
)

group "Distance among structure (m.)"
(
spinner dstruss "Distance" range:[-100,100,0] \
type:#float scale:0.2 fieldwidth:50
)

group "Structure lift Hight (m)"
(
spinner hi "Hight" range:[0,100,0] \
type:#float scale:0.2 fieldwidth:50
)

group "Angle Rotation to Install"
(
spinner ang "Angle (degrees)" range:[-360,360,0] \
type:#float scale:0.2 fieldwidth:50
)

group "Start Time"
(
spinner st "Start at" range:[0,100000,0] \
type:#integer fieldwidth:50
```

```
)

------------------------------------------------------------------
---
-- Design button
------------------------------
button co_simx "Simulate"

on co_simx pressed do
(
------------------------------
-- Assigned Variable Value
------------------------------
tr01 = xspos.value
tr02 = yspos.value
tr03 = struss.value
tr04 = notruss.value
tr05 = dstruss.value
tr06 = hi.value
mum = ang.value


trt01= random 3 5
trt02= random 3 5
trt03= random 3 5
trt04= random 3 5
trt05= random 3 5
trt06= random 3 5
trt07= random 10 15
trt08= random 20 25
trt09= random 7 10
-----------------------------------------
-----------------------------------------
--Simulation time unit (frame per min.)-----
f = 10
-----------------------------------------
--Function Operation----------------------
-----------------------------------------
s=st.value
--(att = average travel time)


ntr = tr04
--total time for body move per 1 cycle
n =
(trt01+trt02+trt03+trt04+trt05+trt06+trt07+trt06+trt07+trt08+trt0
9)*f
------------------------------------------------------------
ttt = ntr*n
ni = s+ttt
--acommulated time frame
------------------------------
x1=0

x3=0
------------------------------
```

```
dis=tr05
for i in s to ni by n do
(
tt01 = (i+trt01*f)
tt02 = (tt01+trt02*f)
tt03 = (tt02+trt03*f)
tt04 = (tt03+trt04*f)
tt05 = (tt04+trt05*f)
tt06 = (tt05+trt06*f)
tt07 = (tt06+trt07*f)
tt08 = (tt07+trt08*f)
tt09 = (tt08+trt09*f)
-----------------------------------------
--Create Time Frame-----------------------
-----------------------------------------

x3=x3+1
if x3<=ntr then
(
AnimationRange = Interval 0 ni
-----------------------------------------
b = tcb_rotation ()
$body02.rotation.controller = b
j = addNewKey b i
j.tension = 50
set animate on
   set time i
   rotate $body02 0 z_axis

j = addNewKey b tt01
j.tension = 50
set animate on
   set time tt01
   rotate $body02 mum z_axis
-----------------------------------------
l = bezier_position ()
$hook01.position.controller = l

k = addNewKey l tt02
k.value = [1,0,-3]
k.outTangentType = #linear

k = addNewKey l tt03
k.value = [6.25,0,3]
k.inTangentType = #linear
k.outTangentType = #step
-----------------------------------------
k = addNewKey l tt04
k.value = [6.25,0,3]
k.outTangentType = #linear

k = addNewKey l tt05
k.value = [1,0,-3]
k.inTangentType = #linear
k.outTangentType = #step
-----------------------------------------
```

```
j = addNewKey b tt06
j.tension = 50
set animate on
   set time tt06
   rotate $body02 0 z_axis

j = addNewKey b tt07
j.tension = 50
set animate on
   set time tt07
   rotate $body02 -mum z_axis

g = bezier_position ()
$wheel02.position.controller = g

k = addNewKey g tt08
k.value = [tr01,tr02,0.5]
k.inTangentType = #step
k.outTangentType = #linear

k = addNewKey g tt09
k.value = [tr01,tr02+tr05,0.5]
k.inTangentType = #linear
k.outTangentType = #step

tr02=tr02+dis

)--end if of machine move
else
endif

-----------------------------------------------
--Excel Chart Present Accumulate Time
-----------------------------------------------
x1=x1+1

if x1!=ntr then
endif
else
(
ExcelApp = CreateOLEObject "excel.application"
ExcelApp.Visible = true
ExcelApp.Workbooks.Add()

(ExcelApp.Range "a1").Value = (tt01)/f
(ExcelApp.Range "a2").Value = (tt02)/f
(ExcelApp.Range "a3").Value = (tt03)/f
(ExcelApp.Range "a4").Value = (tt04)/f
(ExcelApp.Range "a5").Value = (tt05)/f
(ExcelApp.Range "a6").Value = (tt06)/f
(ExcelApp.Range "a7").Value = (tt07)/f
(ExcelApp.Range "a8").Value = (tt08)/f
(ExcelApp.Range "a9").Value = (tt09)/f

(ExcelApp.Range "a1:a9").Select()
```

```
ExcelChart = ExcelApp.Charts.Add()
)--end else of excel
-----------------------------------------
if x1==ntr then
(
time = tt09/f
print "---------------------------------------"
print x1
print "total Operation Time of Mobile Crane"
print time
print "mim."
print "---------------------------------------"
print "total frame"
print tt09
print "---------------------------------------"

)--end for loop of print time
else
endif

)--end for loop of accum. time frame
)--end on button
)--end utility

exc=newrolloutfloater "Roof-Structure Installation Data" 250 200
addrollout trussx exc
exc.size=[250,460]
```

```
--------------------------------------------------------------------
--                    Sort Code
--      for Creating windows Visualizing
--                    created by
--                 Noppadon Jokkaw
--                    Sim-FactoCon Displayer

--------------------------------------------------------------------
rollout rActiveX "Sim-FactoCon"
(
local val
activeXControl ax "{05589FA1-C356-11CE-BF01-00AA0055595A}"
height:700 width:700 align:#left
button btnPick "LOAD Simulated Activity " pos:[720, 10]


on btnPick pressed do
(
local f = getOpenFileName caption:"Pick Any Avi File"
types:"*.avi"
if f != undefined then ax.FileName = f
)

on ax timer do
(
sliderTime = animationRange.start + (ax.CurrentPosition *
(animationRange.end - animationRange.start))/(ax.selectionEnd -
ax.selectionStart)
)
on ax PositionChange oldPos newPos do
(
format "[%, %]\n" oldPos newPos
)
)
nf = newRolloutFloater "Sim-FactoCon (Integrated System for
Factory-Construction Simulation) Developed by CEM Chula" 1050 710
addRollout rActiveX nf
```

```
------------------------------------------------------------------
--              Sort Code
--        for displaying simulation time (1X)
--              created by
--            Noppadon Jokkaw
------------------------------------------------------------------
------------------------------------------------------------------


rollout time1 "Simulation Time 1X-(10fps)"
(
group "Time"
(
label test "0"
label d "min."
)
timer clock "testClock" interval:330
on clock tick do
( x = (test.text as integer)+1
test.text = x as string
)
)

nop=newrolloutfloater "System Output" 160 200
addrollout time1 nop

nop.size=[170,250]
max time play
```

```
--------------------------------------------------------------------
--              Sort Code
--        for displaying simulation time (1/2X)
--              created by
--            Noppadon Jokkaw
--------------------------------------------------------------------
--------------------------------------------------------------------


rollout time1 "Simulation Time 1/2x-(10fps)"
(
group "Time"
(
label test "0"
label d "min."
)
timer clock "testClock" interval:660
on clock tick do
( x = (test.text as integer)+1
test.text = x as string
)
)

nop=newrolloutfloater "System Output" 160 200
addrollout time1 nop

nop.size=[170,250]
max time play
```

VITA

Noppadon Jokkaw was born on February 6, 1969 in Bangkok, Thailand. He received his high school education at Benchamaracharangsarit School in Chachoengsao province. After finished high school, he continued his Bachelor's degree in Civil Engineering at Faculty of Engineering, Chulalongkorn University, Thailand. After graduated in 1993, he worked as a civil engineer in a construction firm for 1 year. He continued studying his master degree in civil engineering at Chulalongkorn University in 1994 and graduated in 1997. While he was studying his Master's degree, he had part-time jobs as a structural engineer in a design company. After he worked as a project manager in construction firm for 1 year and worked as a project coordinator in building-construction project for 1 year. He chose Construction Engineering and Management (CEM) division, Faculty of Engineering, Chulalongkorn University to study in Doctoral program in 1999. Nowadays he and his parent live in Chachoengsao province, Thailand.