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STUDY ON THE PROCESS SIMULATION ALGORITHM OF CEPC ENGINEERING PROJECT

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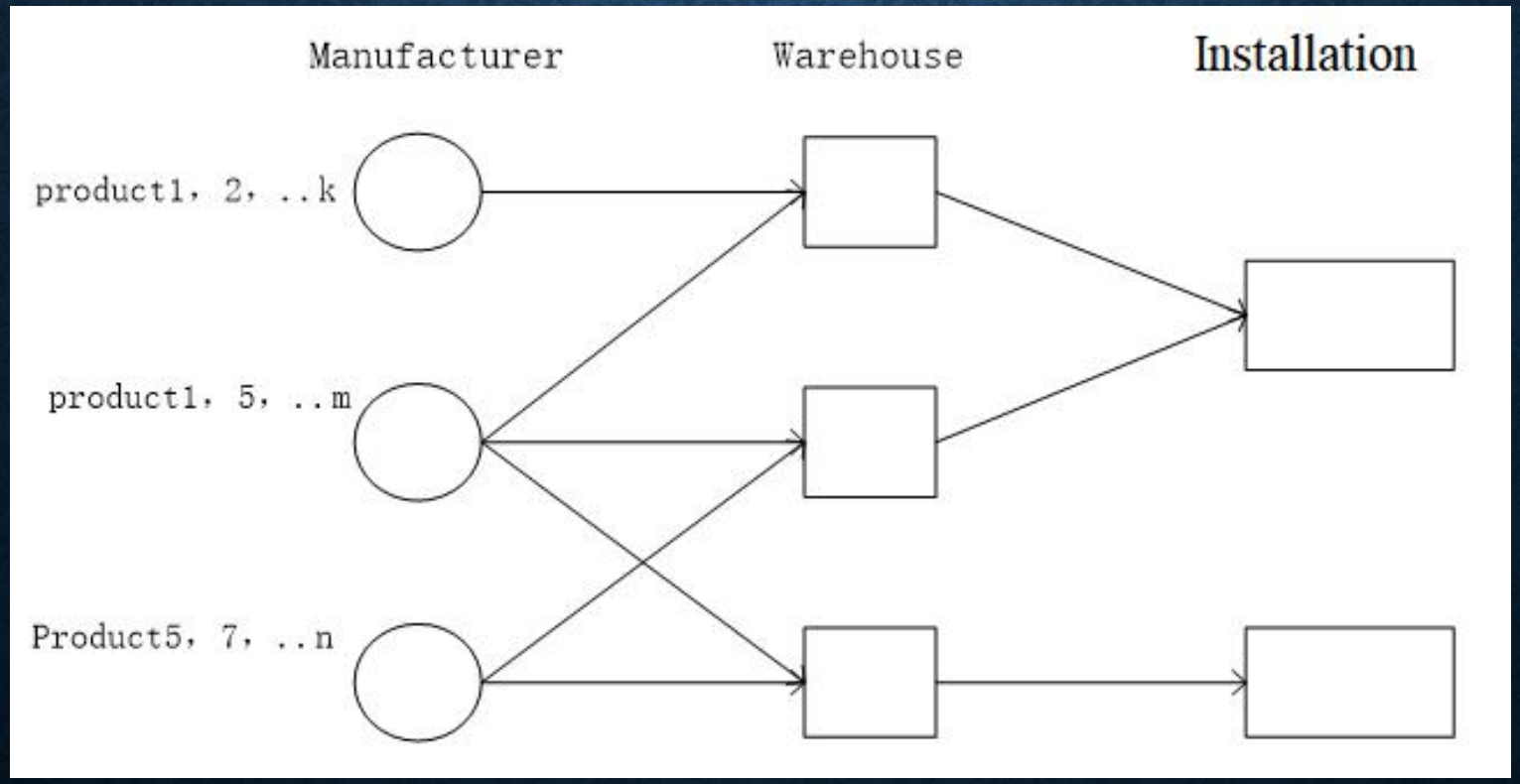
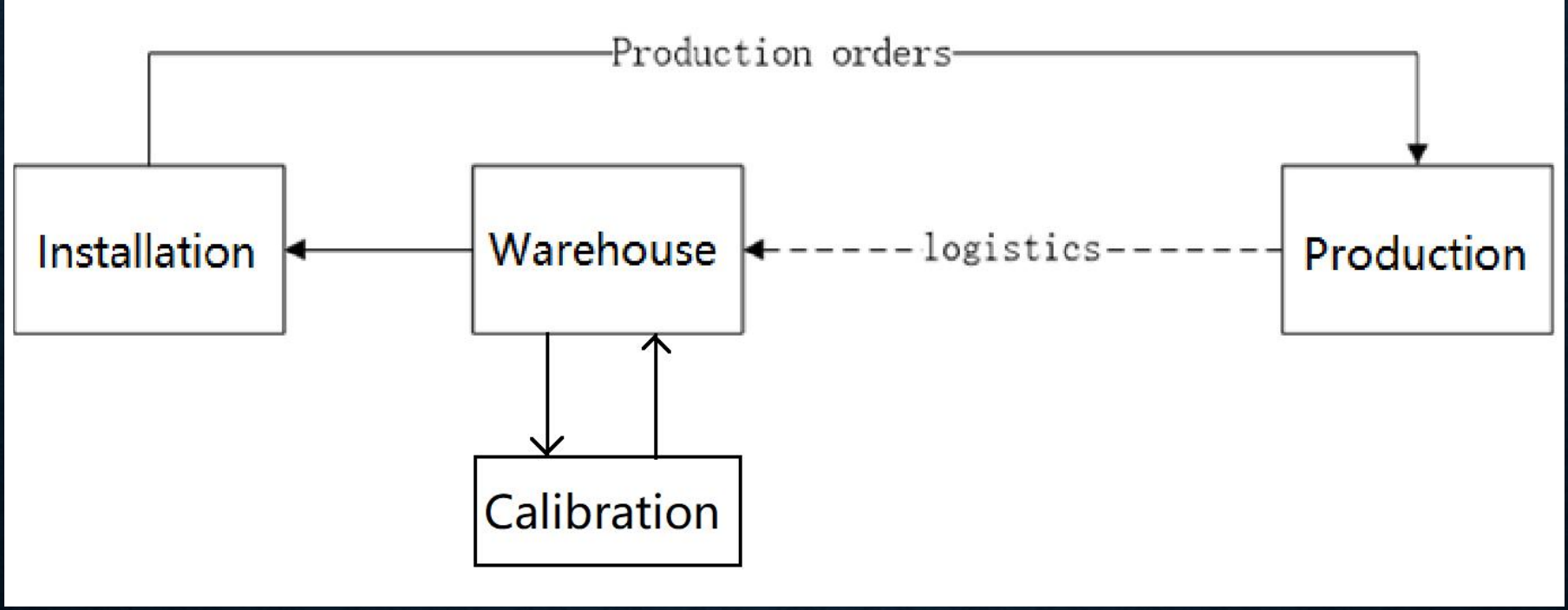
PROCESS SIMULATION SYSTEM DESIGN OF CEPC

- CEPC installation and store is a problem of three stage supply chain

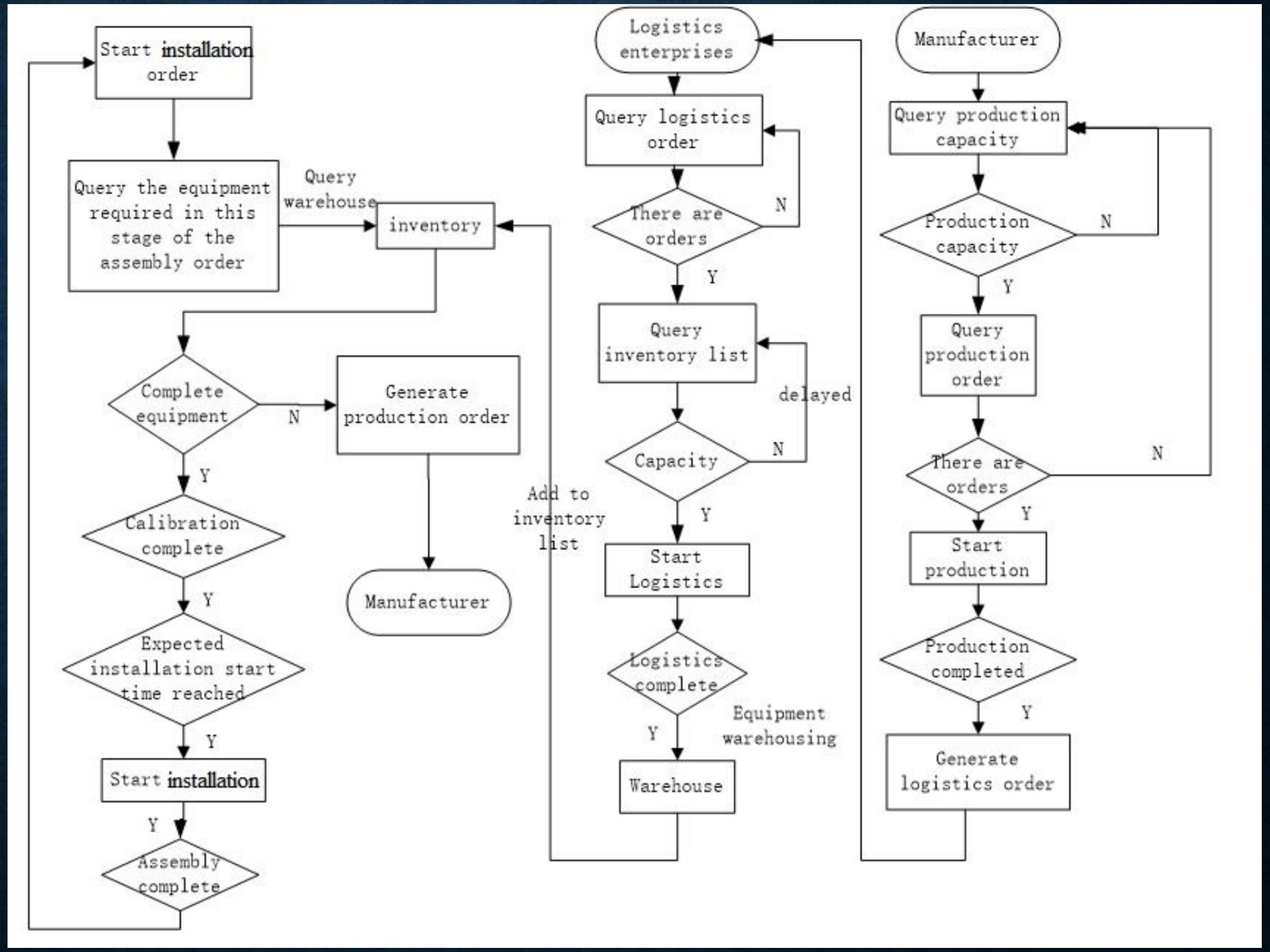


PROCESS SIMULATION SYSTEM DESIGN OF CEPC

- The block diagram and data model of this system



- System flow chart



ALGORITHMIC MODEL

Production processes:

$$\sum_{m=1}^{M} N_{mi}^{k} . Z_{mt}^{k} \geq F_{i}^{k} \quad , \qquad \forall i, k, t$$

$$a_{m}^{k} . \left(N_{mi}^{k} / L_{m}^{k} + \right) \leq tt_{mt}^{k} , \qquad \forall i, k, t, m$$

$$\sum_{j=1}^{J} Nw_{jt}^{k} . W_{jt}^{k} = U_{jmt}^{k} , \quad \forall k, t$$

ALGORITHMIC MODEL

Logistics warehouse link:

$$S_{\mathrm{k}}.Nw_{jt}^{k} \le Ws_{jt} \quad (\mathrm{we_k} \ge 1000), \quad \forall k,t,j \tag{4}$$

$$\mathrm{Nw_{jt}^{k}} \le \mathrm{Wn_{jt}} \quad (\mathrm{we_k} < 1000), \quad \forall k,t,j \tag{5}$$

$$\sum_{\mathrm{j=1}}^{J} U_{jrt}^{k} \ge Cn_{jt}^{k}, \quad \forall k,t \tag{6}$$

$$\mathrm{C_{rt}^{k}} + \mathrm{U_{jrt}^{k}} + \sum_{j=1}^{J} (Cy_{jt}^{k} + \mathrm{Cn_{jt}^{k}}) \ge F_{i}^{k}, \quad \forall k,t \tag{7}$$

$$\sum_{\mathrm{k=1}}^{K} P_{t}^{k}.S_{\mathrm{k}}.C_{rt}^{k} \le Cs_{rt}, \quad \forall t \tag{8}$$

$$\sum_{\mathrm{j=1}}^{J} Cy_{jt}^{k} \ge Sa_{k}, \quad \forall t,k \tag{9}$$

ALGORITHMIC MODEL

The combined effected factor

$$u_{ij} = \frac{f_{ij}}{\sqrt{\lambda_j}} \quad (i=1,2,.....m;\ j=1,2,.....,n) \qquad (10)$$

$$v_i = \sum_{j=1}^{n} u_{ij} s_j \qquad (11)$$

$$w_i = \frac{V_i}{\sum_{i=1}^{n} V_i} \qquad (12)$$

$$x'_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \qquad (13)$$

$$y_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} \quad (i=1,2,.....,m;\ \ j=1,2,.....,n) \qquad (14)$$

$$h_j = -\left(\sum_{i=1}^{m} y_{ij} \ln y_{ij}\right) / \ln n \qquad (15)$$

$$w_j = \frac{1-h_j}{\sum_{j=1}^{m} 1-h_j} \qquad (16)$$

$$w1_j = \frac{(w1_j)^{\alpha}(w2_j)^{1-\alpha}}{\sum_{j=1}^{n}(w1_j)^{\alpha}(w2_j)^{1-\alpha}} \qquad (17)$$

$$\sum_{j=1}^{n} w1_j = 1 \qquad (18)$$

$$f = \sum_{j=1}^{n} w1_j . r_{jt}\ , \quad \forall t \qquad (19)$$

DESIGN OF TIMELINE

- In order to construct the simulation process, a virtual timeline models must be designed. The timeline simulate the passage of time to control the entire simulation process. The timeline is designed to be scalable, which means that the relationship between virtual time and real time can be adjusted. Following is the algorithm:

$$t_v = kt_r$$

t_v Virtual time t_r real time k Scaling factor $0 < k \leq 1$。

- The value of t[illegible]s too large, it will take a lot of time. If it is too small, the simulation accuracy will be reduced, and even make error during the simulation process. Here we take k=1/3600 here.

DESIGN OF TIMELINE

Simulation visualization parameter

$$\mathrm{tv} = sf.tr\ ,\ sf \in (0,1) \tag{20}$$

$$\mathrm{Tr_{it}} = Ts_{it}.(1+0.01f)\ ,\quad \forall t,\mathrm{i} \tag{21}$$

$$Ts_{\mathrm{it}} = 1/Tr_{it}.Ts_{i(t-1)}\ ,\quad \forall t \tag{22}$$

$$Status_{it} = Status_{i(\mathrm{t\text{-}1})} + 1/Tr_{it}.(1 - Status_{i(\mathrm{t\text{-}1})}.0.01)\ ,\quad \forall t \tag{23}$$

INSTANCE OF THE 12.5 KM TEST SECTION

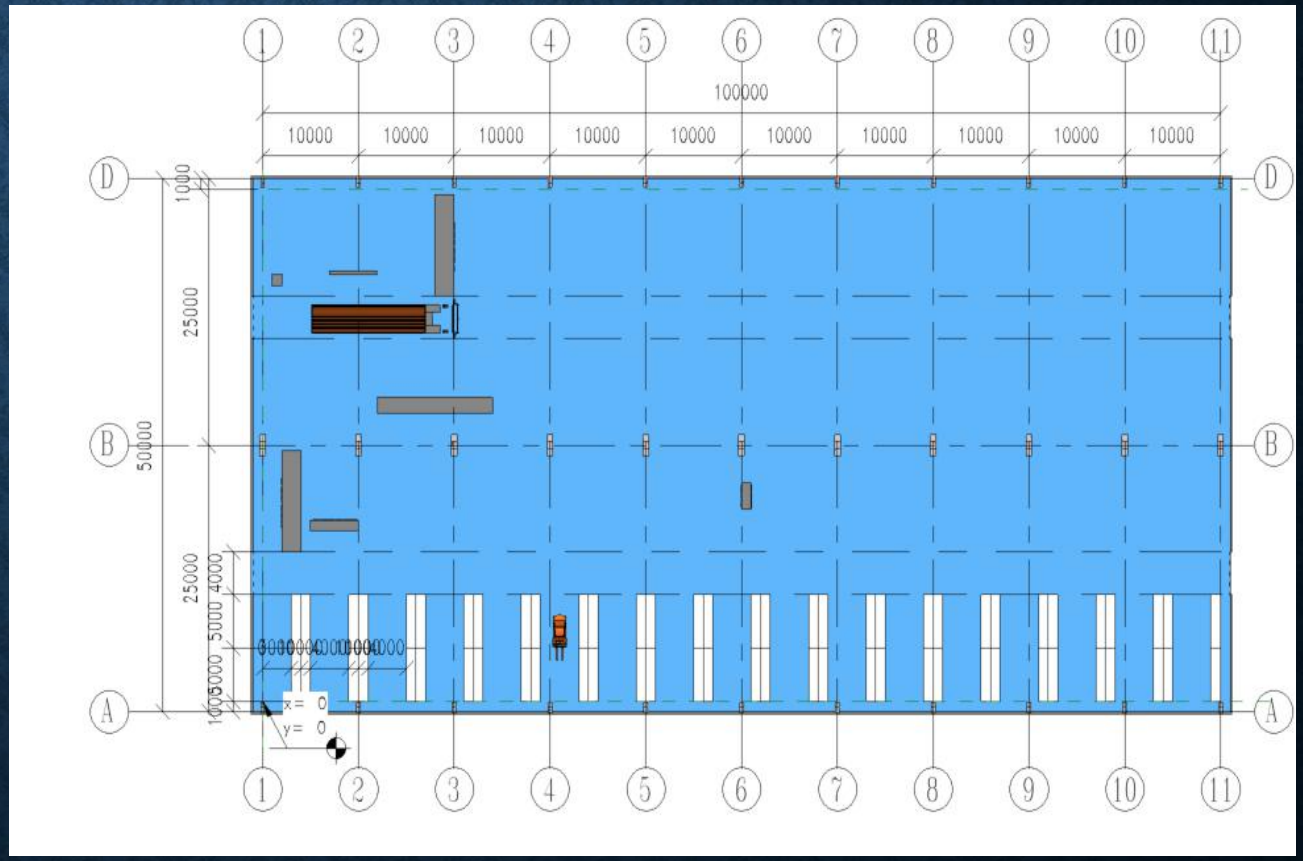
- Following list is equipments needed in this instance
- Parameter 1：
- 1、A test section is 12.5 km long
- 2、Start time of simulation：2020-08-07
- 3、70 manufacturers

要仿真的装配订单的零件列表：

装配订单编号（assOrderID）	设备类型（equcategoryID）	数量	所属装配标段	安装开始启动时间
assO001	主环标准周期二极铁	1400	1	2028/3/01
assO002	主环标准周期二极铁	1400	2	2028/4/25
assO003	主环标准周期二极铁	1400	3	2028/6/18
assO004	主环标准周期二极铁	1400	4	2028/8/10
assO005	主环标准周期四极铁	280	1	2028/10/1
assO006	主环标准周期四极铁	280	2	2028/10/6
assO007	主环标准周期四极铁	280	3	2028/10/11
assO008	主环标准周期四极铁	280	4	2028/10/16
assO009	主环标准周期六极铁 1	56	1	2028/10/23
assO010	主环标准周期六极铁 1	56	2	2028/10/24
assO011	主环标准周期六极铁 1	56	3	2028/10/25
assO012	主环标准周期六极铁 1	56	4	2028/10/26
assO013	主环标准周期校正铁	280	1	2028/11/1
assO014	主环标准周期校正铁	280	2	2028/11/5
assO015	主环标准周期校正铁	280	3	2028/11/8
assO016	主环标准周期校正铁	280	4	2028/11/11
assO017	主环标准周期 BPM	280	1	2028/11/16
assO018	主环标准周期 BPM	280	2	2028/11/20
assO019	主环标准周期 BPM	280	3	2028/11/24
assO020	主环标准周期 BPM	280	4	2028/12/28
assO021	主环恒温器	20	1	2028/12/1
assO022	主环超导四极铁	4	3	2028/12/1
assO064	booster 标准周期 BPM	200	2	2029/2/3
assO065	booster 标准周期 BPM	200	3	2029/2/6
assO066	booster 标准周期 BPM	200	4	2029/2/9
assO067	booster 恒温器	6	1	2029/2/12
assO068	booster 切割铁	16	1	2029/2/12
assO069	boosterkicker	4	1	2029/2/12
assO070	booster 非标准周期二极铁	40	13	2029/2/12
assO071	booster 非标准周期二极铁	40	2	2029/2/14
assO072	booster 非标准周期二极铁	40	3	2029/2/16
assO073	booster 非标准周期二极铁	40	4	2029/2/18
assO074	booster 非标准周期四极铁	54	1	2029/2/20
assO075	booster 非标准周期四极铁	54	2	2029/2/21
assO076	booster 非标准周期四极铁	55	3	2029/2/23
assO077	booster 非标准周期四极铁	55	4	2029/2/24
assO078	booster 非标准周期六极铁	37	1	2029/2/26
assO079	booster 非标准周期六极铁	38	2	2029/2/26
assO080	booster 非标准周期六极铁	38	3	2029/2/27
assO081	booster 非标准周期六极铁	37	4	2029/2/28
assO082	主环标准周期六极铁 2	56	1	2028/10/27
assO083	主环标准周期六极铁 2	56	2	2028/10/28
assO084	主环标准周期六极铁 2	56	3	2028/10/29
assO085	主环标准周期六极铁 2	56	4	2028/10/30
assO086	主环非标准周期六极铁 2	30	1	2029/1/28
assO087	主环非标准周期六极铁 2	30	2	2029/1/29
assO088	主环非标准周期六极铁 2	30	3	2029/1/30
assO089	主环非标准周期六极铁 2	30	4	2029/1/31

INSTANCE OF THE 12.5 KM TEST SECTION

- Parameter 2:
- 1、Layout of the warehouse in right
- 2、 Specifications of warehouse: 100m*50m
- 3、warehouse type1（only stacking area），the areas is about 4000m2。
- 4、warehouse type2（with shelf），the areas is about 3000m2，the number of shelf is 264.



INSTANCE OF THE 12.5 KM TEST SECTION

- Warehouse model

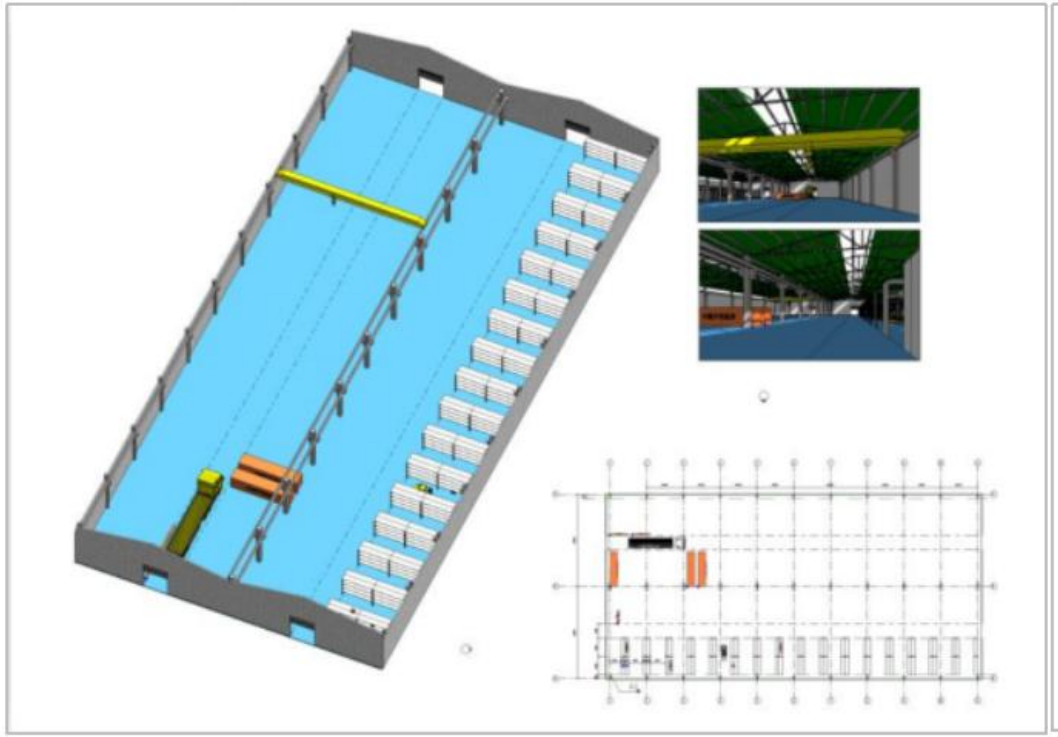


Figure 4 warehouse layout (1)

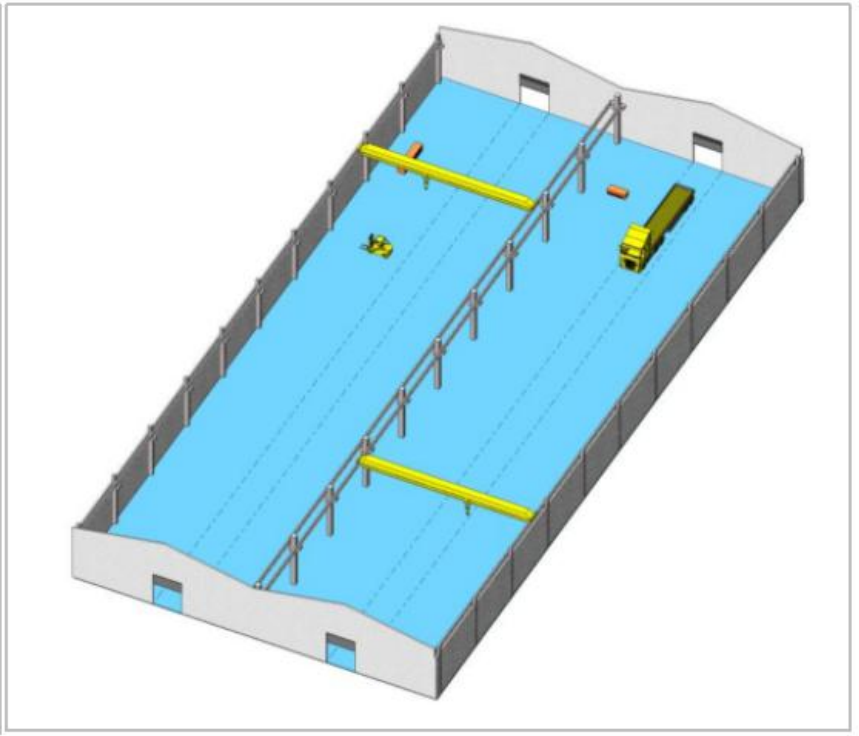


Figure 5 warehouse layout (2)

INSTANCE OF THE 12.5 KM TEST SECTION

- Equipment parameters (part of)

Equipment name	quantity	External dimension	Equipment weight / kg	Calibration / installation sequence	Note: is it possible to calibrate / install in parallel
Standard Period Diode Iron of Main Ring	5600	5.67*0.53*0.14	3000	1	yes
Main ring standard period quadrupole iron	1120	2*0.7*0.56	6500	2	yes
Main ring standard period hexapole iron	448	1.4*0.34*0.345	1400	3	yes
Main ring standard period correction iron	1120	0.9*0.5*0.5	1900	4	no

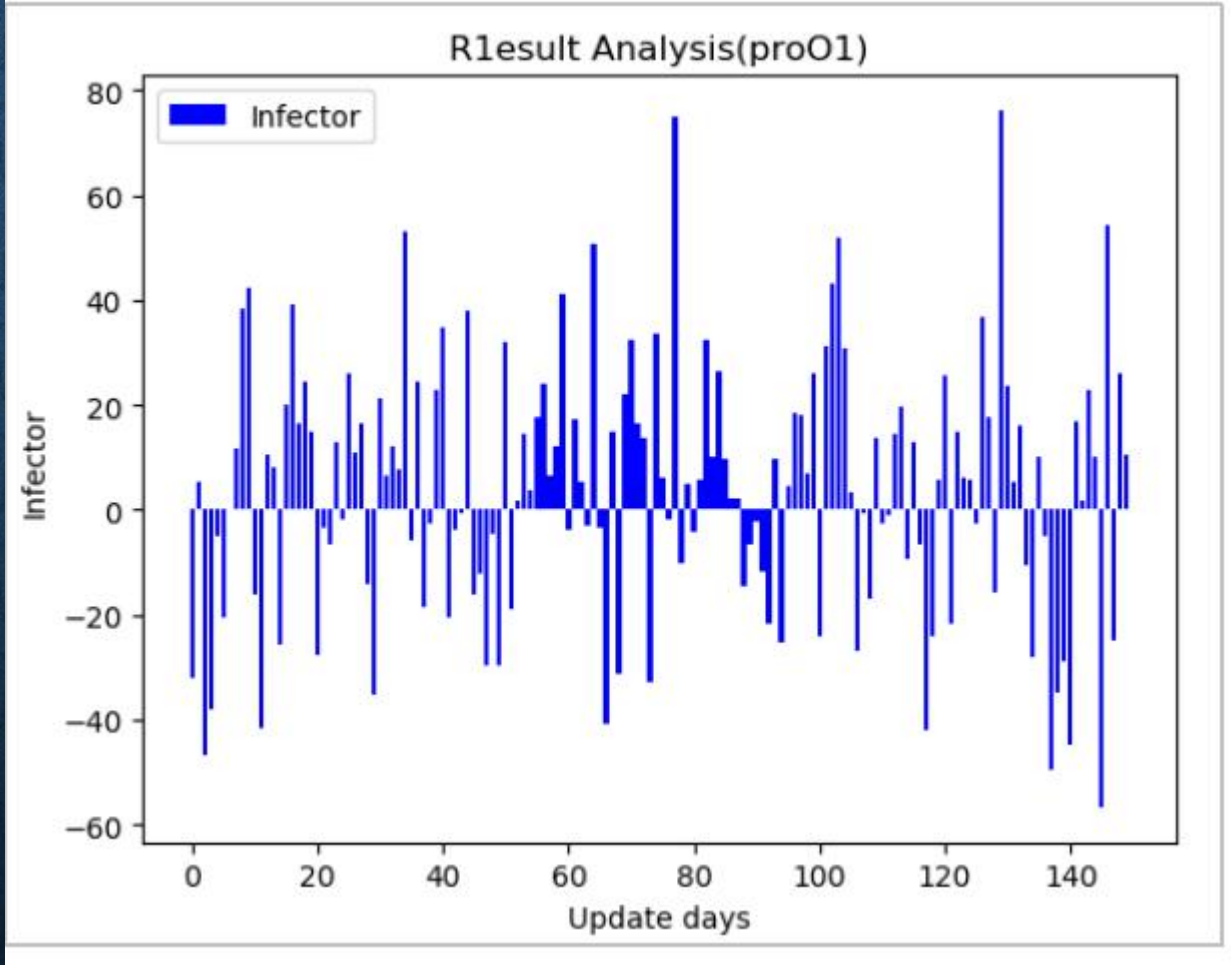
INSTANCE OF THE 12.5 KM TEST SECTION

- Process timetable (part of)

Equipment name	Calibration start time	Calibration end time	Calibration speed: set / day	Installation start time	Installation end time	Install-ation speed: set / day
Standard Period Diode Iron of Main Ring	2024/1/7	2025/11/9	10	2028/3/1	2028/9/30	32
Main ring standard period quadrupole iron	2025/11/9	2026/1/16	20	2028/10/1	2028/10/22	64
Main ring standard period hexapole iron	2026/1/16	2026/2/12	20	2028/10/23	2028/10/31	64
Main ring standard period correction iron	2026/2/12	2026/3/18	40	2028/11/1	2028/11/15	96

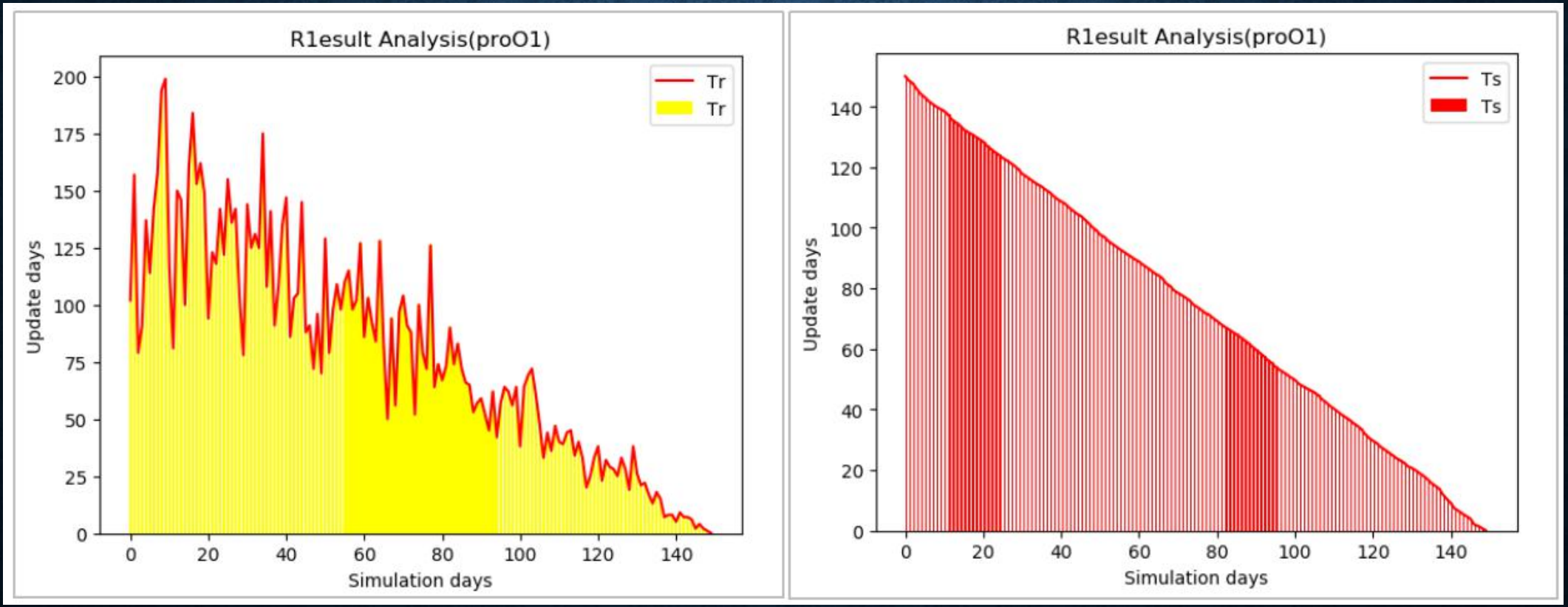
SIMULATION RESULTS

- The combined effects of factors



SIMULATION RESULTS

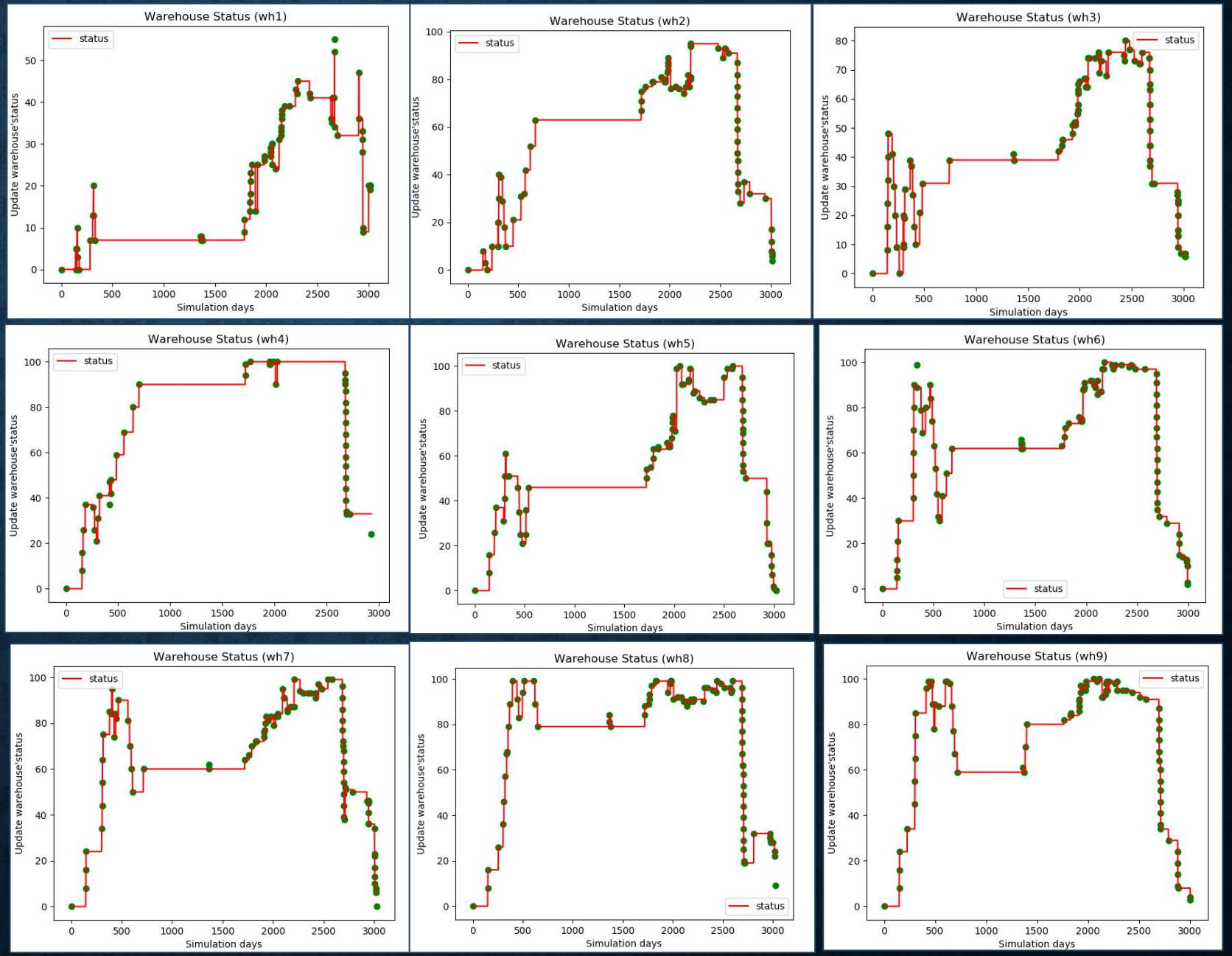
- Tr & Ts



SIMULATION RESULTS

- Warehouse utilization

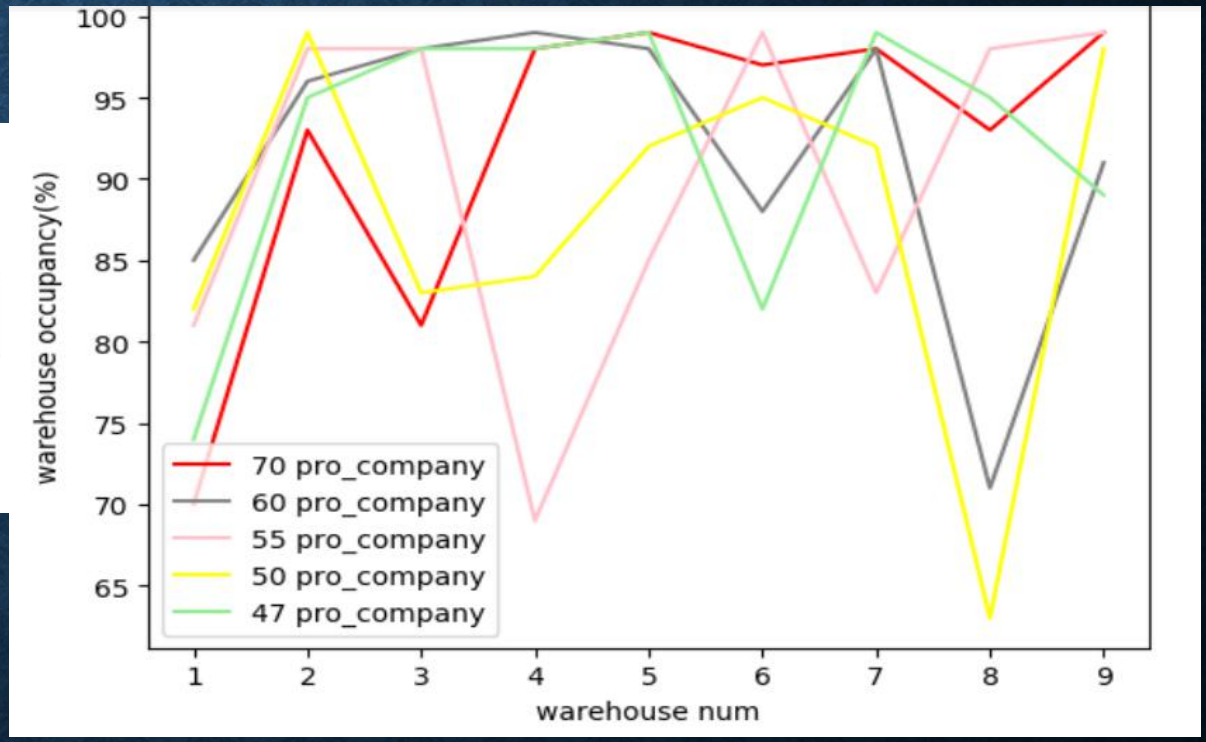
（part of）



MODEL VALIDATION TESTS

- Change the number of Manufacturer

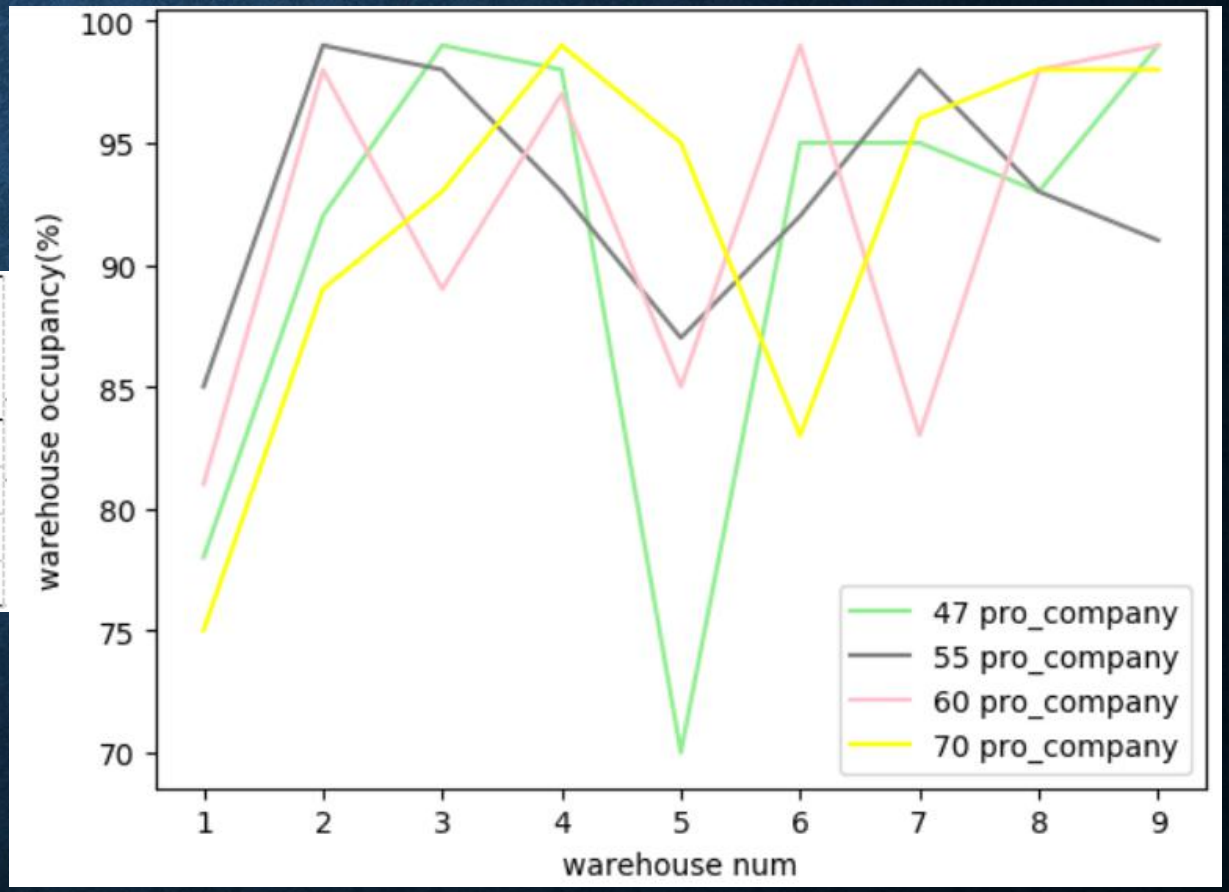
Number of production companies/warehouse number	1	2	3	4	5	6	7	8	9	Delay days of construction period
70	70	93	81	98	99	98	98	93	99	3
60	85	96	98	99	98	88	98	71	91	8
55	81	98	98	69	85	99	83	98	99	4
50	82	99	83	84	92	95	92	63	98	15
47	74	95	98	98	99	82	99	95	89	7



MODEL VALIDATION TESTS

- Change the start time of the production order

Number of manufacturing enterprises / warehouse number	1	2	3	4	5	6	7	8	9	Delay days of construction period
70	75	89	93	99	95	83	96	98	99	13
60	81	98	89	97	85	99	83	98	99	167
55	85	99	97	87	92	98	97	98	93	180
47	78	92	99	98	70	95	95	99	98	230



INSTANCE OF THE 12.5 KM TEST SECTION

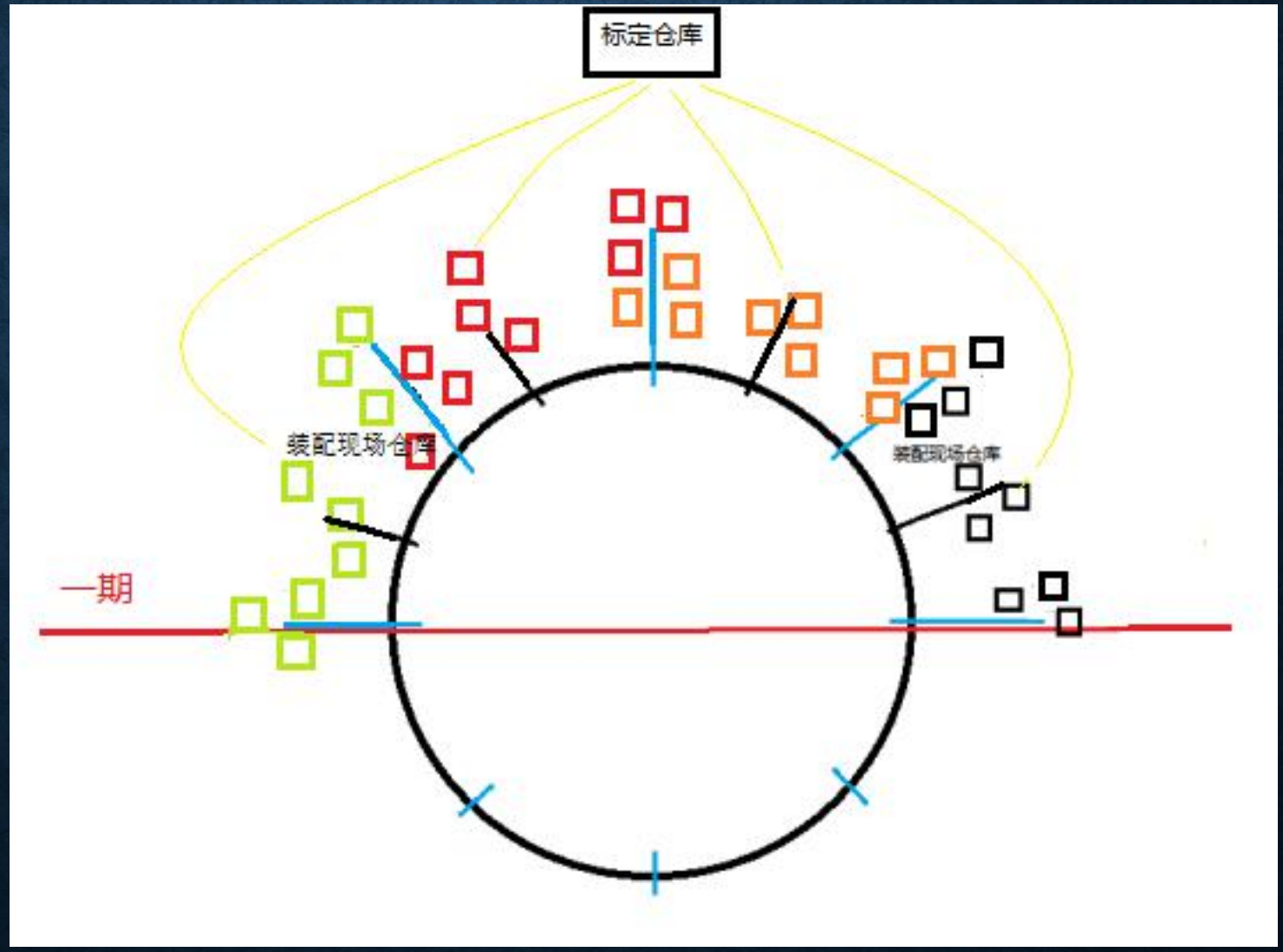
Interface of simulation system

INSTANCE OF THE 12.5 KM TEST SECTION

Interface of simulation system

INSTANCE OF THE 12.5 KM TEST SECTION

- Warehouse layout



INSTANCE OF THE 12.5 KM TEST SECTION

- Simulation result:
- the number of warehouses at each horizontal cave entrance is 2 in this test section , one of the warehouse with shelf.
- simulation start time：2020-8-7
- schedule end time：2029-2-28
- actual end time：2029-3-2，delay 3 days。
- The running time of the computer：26h25m31s。
- Numbers of Warehouse:36
- Numbers of Calibration Warehouse:1

LOG FILE OF THE PROCESS SIMULATION

```
2020-08-07 19:53:21,479 - newcalass2020805.py[line:1073] - INFO: proO9的当前进度为:0.0
2020-08-07 19:53:22,300 - newcalass2020805.py[line:1073] - INFO: proO7的当前进度为:1.0
2020-08-07 19:53:22,302 - newcalass2020805.py[line:1073] - INFO: proO5的当前进度为:1.0
2020-08-07 19:53:22,302 - newcalass2020805.py[line:1073] - INFO: proO3的当前进度为:1.0
2020-08-07 19:53:23,115 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO19）进度的因素：原材料采购; 当天该因素产生的随机值：-53; 该因素的权重：0.17
2020-08-07 19:53:23,115 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO19）进度的因素：资金问题; 当天该因素产生的随机值：70; 该因素的权重：0.15
2020-08-07 19:53:23,115 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO19）进度的因素：生产能力; 当天该因素产生的随机值：89; 该因素的权重：0.19
2020-08-07 19:53:23,115 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO19）进度的因素：仓库问题; 当天该因素产生的随机值：8; 该因素的权重：0.17
2020-08-07 19:53:23,116 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO19）进度的因素：停水停电问题; 当天该因素产生的随机值：-15; 该因素的权重：0.17
2020-08-07 19:53:23,116 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO19）进度的因素：其他因素; 当天该因素产生的随机值：36; 该因素的权重：0.15
2020-08-07 19:53:23,116 - newcalass2020805.py[line:1038] - INFO: 订单proO19在[2020-11-14]时刻的综合影响因子为：22.61
2020-08-07 19:53:23,183 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO21）进度的因素：原材料采购; 当天该因素产生的随机值：36; 该因素的权重：0.17
2020-08-07 19:53:23,183 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO21）进度的因素：资金问题; 当天该因素产生的随机值：-53; 该因素的权重：0.15
2020-08-07 19:53:23,183 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO21）进度的因素：生产能力; 当天该因素产生的随机值：-40; 该因素的权重：0.19
2020-08-07 19:53:23,183 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO21）进度的因素：仓库问题; 当天该因素产生的随机值：94; 该因素的权重：0.17
2020-08-07 19:53:23,183 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO21）进度的因素：停水停电问题; 当天该因素产生的随机值：95; 该因素的权重：0.17
2020-08-07 19:53:23,184 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO21）进度的因素：其他因素; 当天该因素产生的随机值：41; 该因素的权重：0.15
2020-08-07 19:53:23,184 - newcalass2020805.py[line:1038] - INFO: 订单proO21在[2020-11-14]时刻的综合影响因子为：28.85
2020-08-07 19:53:23,449 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO23）进度的因素：原材料采购; 当天该因素产生的随机值：-77; 该因素的权重：0.17
2020-08-07 19:53:23,449 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO23）进度的因素：资金问题; 当天该因素产生的随机值：-20; 该因素的权重：0.15
2020-08-07 19:53:23,450 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO23）进度的因素：生产能力; 当天该因素产生的随机值：-19; 该因素的权重：0.19
2020-08-07 19:53:23,450 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO20）进度的因素：原材料采购; 当天该因素产生的随机值：79; 该因素的权重：0.17
2020-08-07 19:53:23,450 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO23）进度的因素：仓库问题; 当天该因素产生的随机值：-25; 该因素的权重：0.17
2020-08-07 19:53:23,451 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO20）进度的因素：资金问题; 当天该因素产生的随机值：59; 该因素的权重：0.15
2020-08-07 19:53:23,451 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO23）进度的因素：停水停电问题; 当天该因素产生的随机值：-37; 该因素的权重：0.17
2020-08-07 19:53:23,451 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO20）进度的因素：生产能力; 当天该因素产生的随机值：-33; 该因素的权重：0.19
2020-08-07 19:53:23,451 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO23）进度的因素：其他因素; 当天该因素产生的随机值：-86; 该因素的权重：0.15
2020-08-07 19:53:23,452 - newcalass2020805.py[line:1038] - INFO: 订单proO23在[2020-11-14]时刻的综合影响因子为：-43.14
2020-08-07 19:53:23,452 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO20）进度的因素：仓库问题; 当天该因素产生的随机值：-3; 该因素的权重：0.17
2020-08-07 19:53:23,452 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO20）进度的因素：停水停电问题; 当天该因素产生的随机值：19; 该因素的权重：0.17
2020-08-07 19:53:23,452 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO20）进度的因素：其他因素; 当天该因素产生的随机值：-90; 该因素的权重：0.15
2020-08-07 19:53:23,452 - newcalass2020805.py[line:1038] - INFO: 订单proO20在[2020-11-14]时刻的综合影响因子为：5.23
2020-08-07 19:53:23,501 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO2）进度的因素：原材料采购; 当天该因素产生的随机值：30; 该因素的权重：0.17
2020-08-07 19:53:23,501 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO2）进度的因素：资金问题; 当天该因素产生的随机值：16; 该因素的权重：0.15
2020-08-07 19:53:23,501 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO2）进度的因素：生产能力; 当天该因素产生的随机值：-33; 该因素的权重：0.19
2020-08-07 19:53:23,501 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO2）进度的因素：仓库问题; 当天该因素产生的随机值：-27; 该因素的权重：0.17
2020-08-07 19:53:23,501 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO2）进度的因素：停水停电问题; 当天该因素产生的随机值：83; 该因素的权重：0.17
2020-08-07 19:53:23,501 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO2）进度的因素：其他因素; 当天该因素产生的随机值：-34; 该因素的权重：0.15
2020-08-07 19:53:23,501 - newcalass2020805.py[line:1038] - INFO: 订单proO2在[2020-11-14]时刻的综合影响因子为：5.65
2020-08-07 19:53:23,586 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO22）进度的因素：原材料采购; 当天该因素产生的随机值：-18; 该因素的权重：0.17
2020-08-07 19:53:23,586 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO22）进度的因素：资金问题; 当天该因素产生的随机值：-19; 该因素的权重：0.15
2020-08-07 19:53:23,586 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO22）进度的因素：生产能力; 当天该因素产生的随机值：32; 该因素的权重：0.19
2020-08-07 19:53:23,586 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO22）进度的因素：仓库问题; 当天该因素产生的随机值：5; 该因素的权重：0.17
2020-08-07 19:53:23,586 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO22）进度的因素：停水停电问题; 当天该因素产生的随机值：-18; 该因素的权重：0.17
2020-08-07 19:53:23,587 - newcalass2020805.py[line:1094] - INFO: 影响生产(proO22）进度的因素：其他因素; 当天该因素产生的随机值：72; 该因素的权重：0.15
2020-08-07 19:53:23,587 - newcalass2020805.py[line:1038] - INFO: 订单proO22在[2020-11-14]时刻的综合影响因子为：8.76
```

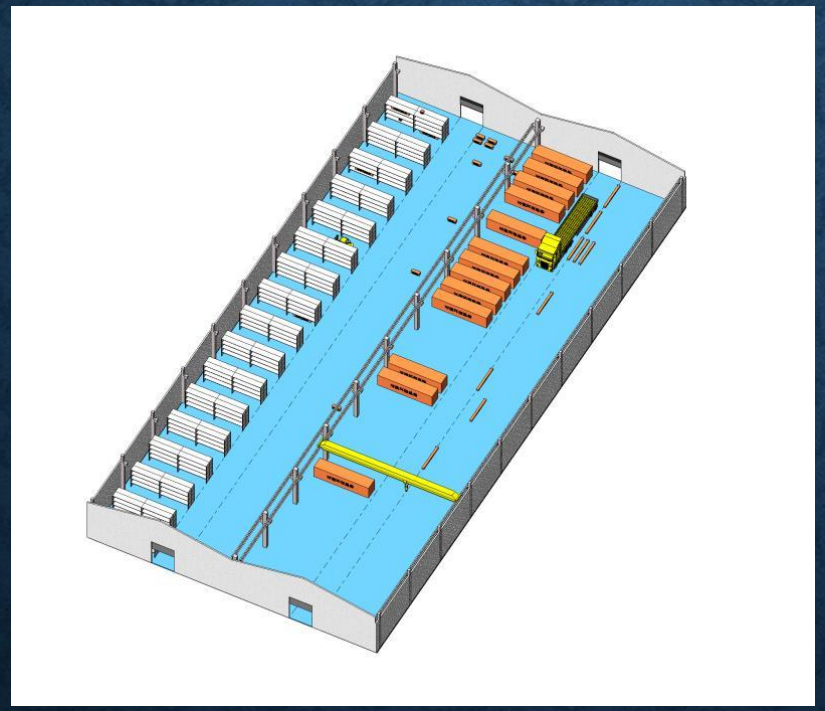
WAREHOUSE SIMULATION PROCESS OUTPUT TO BIM

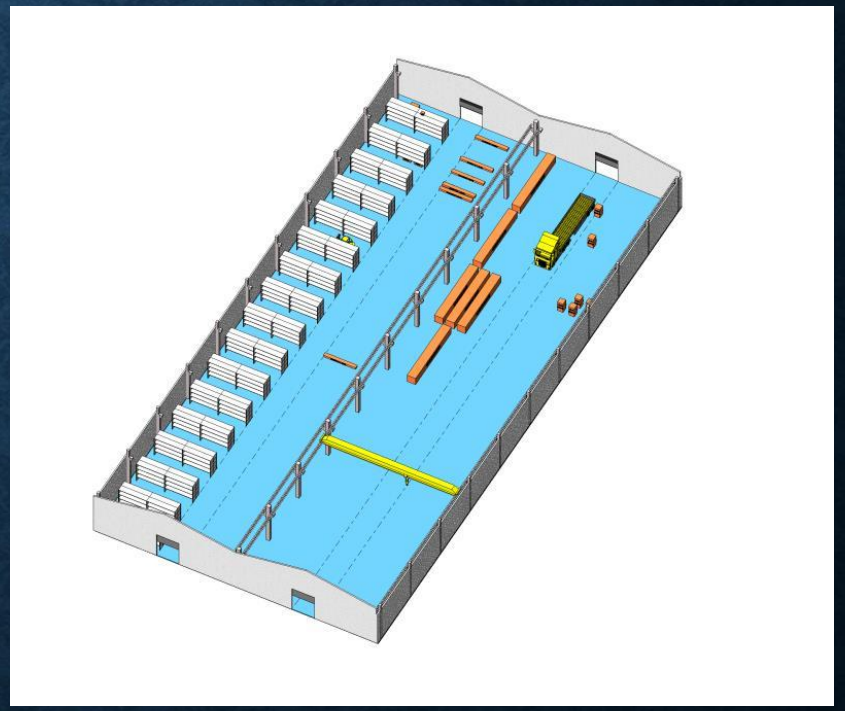
- The simulation process is combined and sharing the database with BIM, use BIM for 3D modeling , and to display warehouse usage rate . This make the process intuitive. The table in right is the data shared with BIM.
- Inventory out also can be displayed by BIM in 3D model。

字段	字段类型	说明
设备编号	Vchar(20)	设备编号
设备类名称	Vchar(30)	设备类名称
仓库组X坐标	int	X坐标
仓库组Y坐标	int	Y坐标
仓库X坐标	int	X坐标
仓库Y坐标	int	Y坐标
堆货区X坐标	int	X坐标
堆货区Y坐标	int	Y坐标
堆货单元X坐标	int	X坐标
堆货单元Y坐标	int	Y坐标
堆放规则	int	0表示横放，1表示竖放
货架X坐标	int	X坐标
货架Y坐标	int	Y坐标
货架单元X坐标	int	X坐标
货架单元Y坐标	int	Y坐标
货架单元Z坐标	int	Z坐标

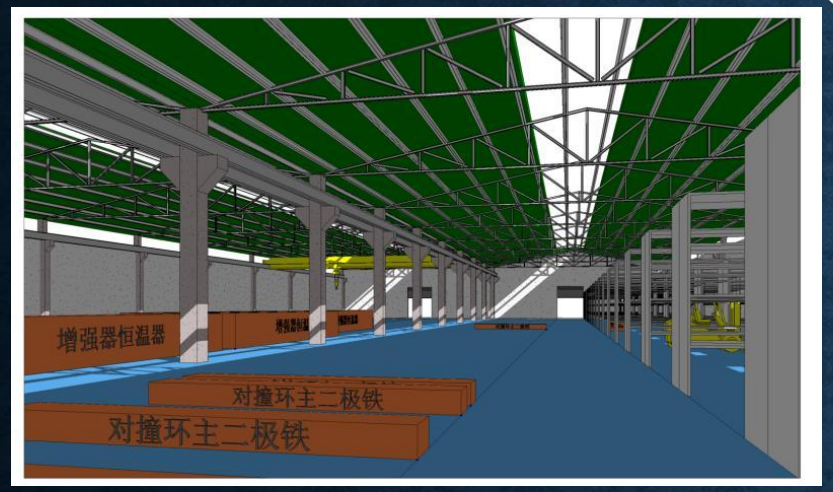
WAREHOUSE SIMULATION PROCESS OUTPUT TO BIM

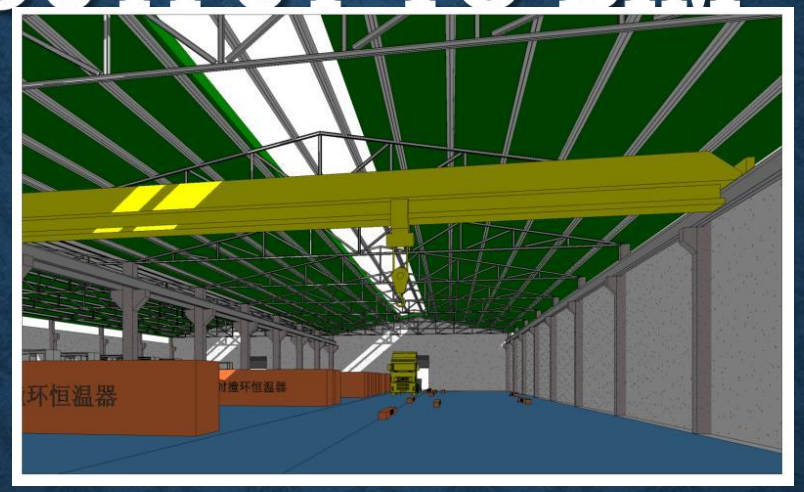
- The result of warehouse 3D model display.

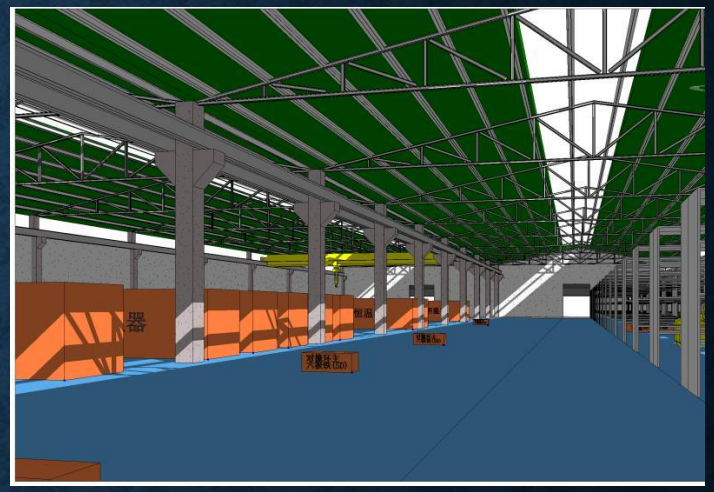


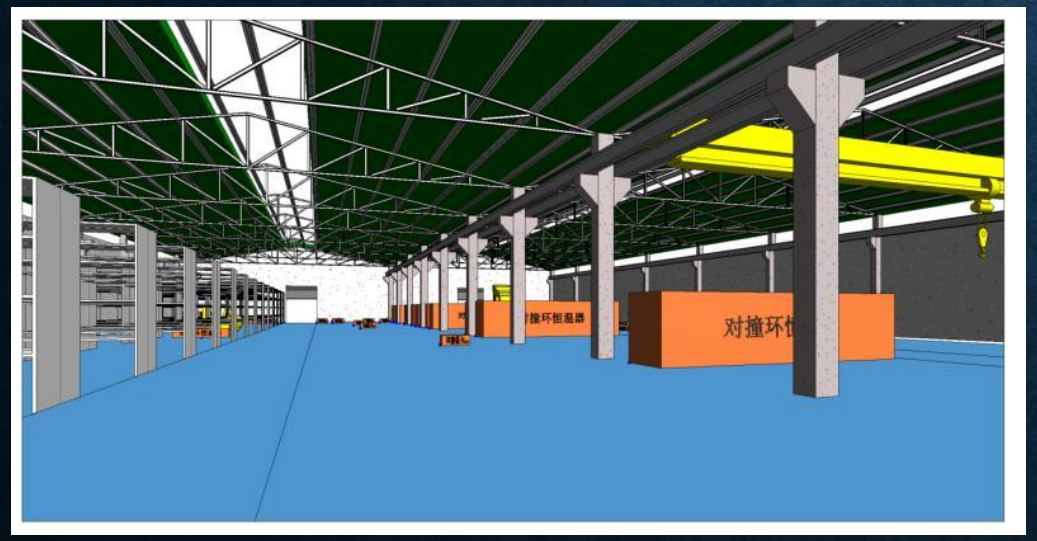


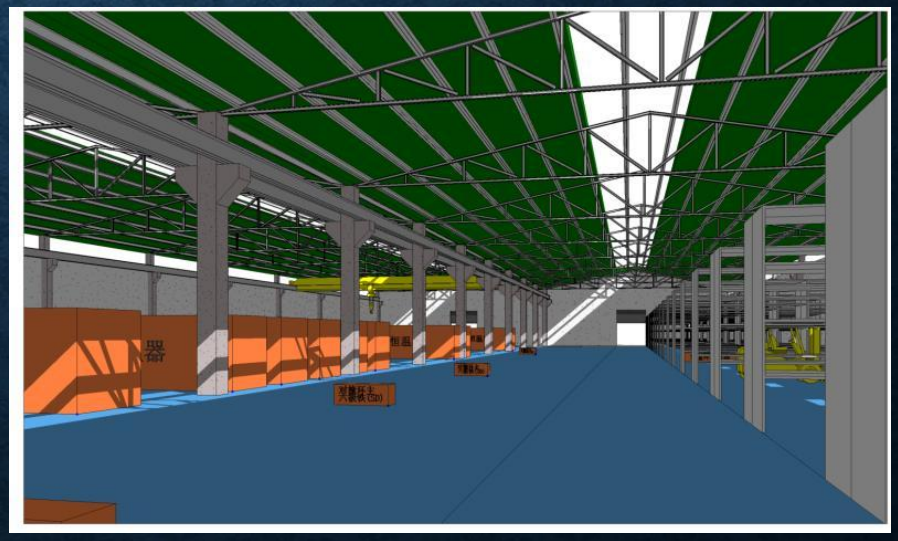
WAREHOUSE SIMULATION PROCESS OUTPUT TO BIM











THANKS!

- Nov. 2021
- Online by Zoom, China.