# INVENTORY OPTIMIZATION IN REPETITIVE MANUFACTURING

## ОПТИМИЗАЦИЯ НА ИНВЕНТАРА ПРИ СТАНДАРТНО ПРОИЗВОДСТВО

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**Abstract**

This contribution is focused on the key requirements for efficient pull system operation in repetitive manufacturing companies. The target of the described model is to operate with optimal level of inventory in a plant in order to achieve highest efficiency of production (lowest costs). A model of production pattern evaluation and safety stock calculation is proposed. This model is suitable for production lines operating at nearly 100% of their capacities.

**Introduction**

In order to run JIT in manufacturing company a pull system operation is a must. The pull system itself is best to run by using kanban as a trigger for all production flow. Kanban operation will work sufficiently from physical flow point of view only in case those three necessary conditions are achieved: Best production pattern, Production leveling and low safety stock.

**Pull system, stock optimization**

Pull system stands on 3 essential pillars:

1. Production pattern
2. Production leveling
3. Requested volume production

Besides pure pull system with JIT concept most of repetitive manufacturing companies have to consider also other manufacturing aspects which affect the total production pattern efficiency:

1) Changeovers
2) Not good adjustment products (changeover products)
3) Maximum operation stock level opportunity costs
4) Operation stock not good parts (from last period rejections (sorting))
5) Operation stock sorting time (in case of problem found)

These parameters are limited by following constraints:

1) Minimal lot size
2) First produced part quality confirmation lead-time

The lower the inventory level is the more line changeovers must be done. By increasing the number of changeovers an important breakpoint on time axis will occur once meantime between 2 changeovers becomes shorter than first part quality confirmation lead-time. At this point there is a risk that all produced parts will be scrapped (if measurement result is not good). Second mirror effect of reducing inventory level by increasing number of line changeovers is that line efficiency (output) becomes lower, because each changeover consumes production time of the line.

**Production pattern**

a) Fixed Time and Any quantity

- The Customer Order results are reflected straight.

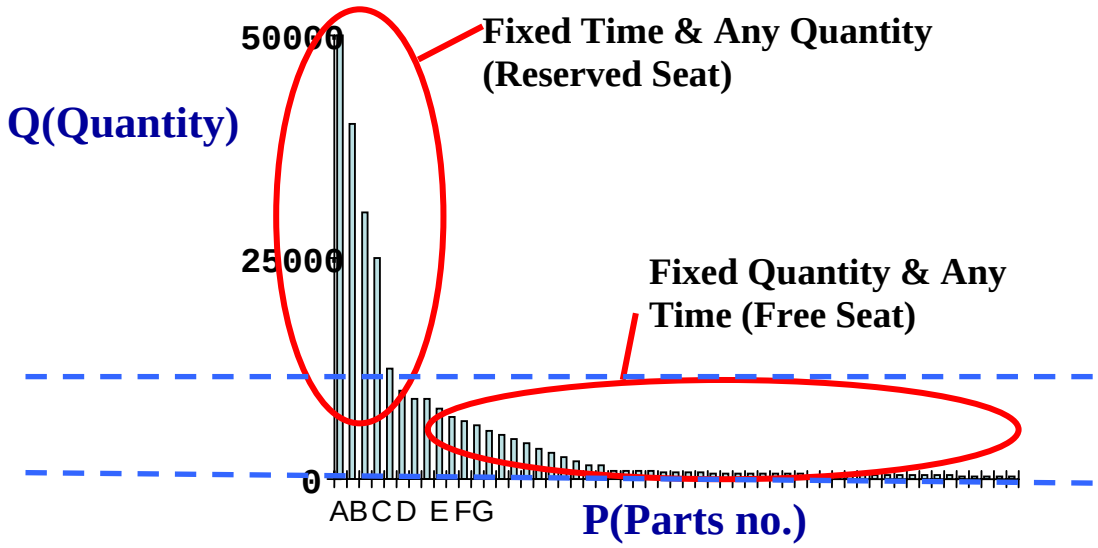
This means that a logistics unit (material, product,…) is replenished in fixed time period by a quantity which was consumed in previous time slot

b) Fixed Quantity & Any Time

Accumulate customer order results, and produce when it reaches to the standard lot.

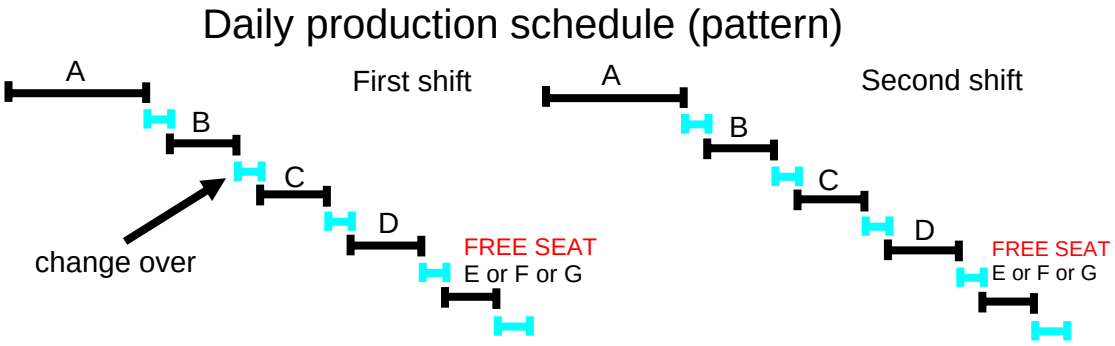
The Fixed time and any quantity method is optimal for high volume production – repetitive production (“big sales”). Fixed qty and any time should be used for small volume production (small production lots, many parts produced, production on customer demand).

*Figure 1: Decision making for production pattern*




Based on the product matrix (parts versus quantities) evaluation and optimal production pattern can be created.

*Figure 2: Production pattern*




**Production leveling**
Production leveling is a second pillar which is necessary for correct function of pull system. Production leveling means balanced production – to produce the same quantity of product within as short period as possible. Generally we can imagine the balanced production if there is same qty (e.g. +/- □%) produced every day and even every hour. This enables clear calculation and assignment of necessary resources (human, machines capacities, handling equipment) and it's up to 100% utililization in long term point of view. The daily variation +/- □% allows absorbing customer order fluctuation (variances against forecasted quantities). The variance +/- □% should be low (e.g. +/- □%) in order to keep levelized volume.

*Figure 3: Production without leveling (balancing)*

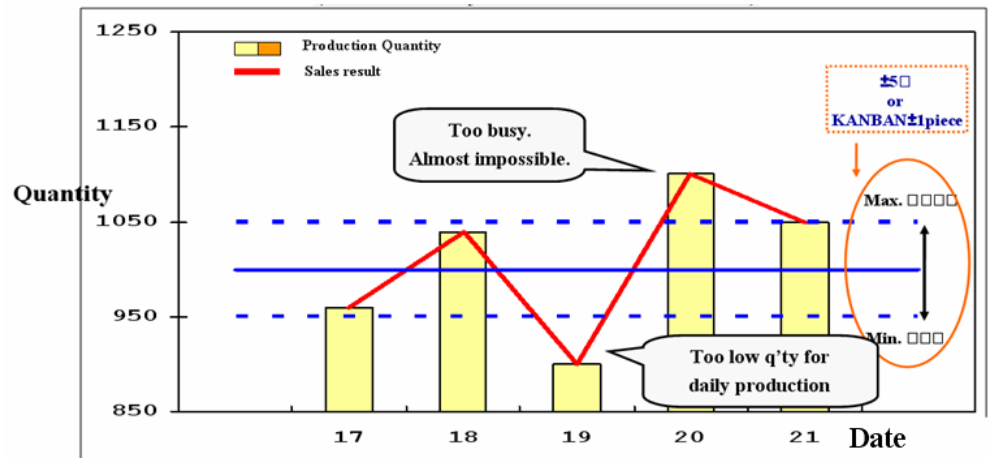
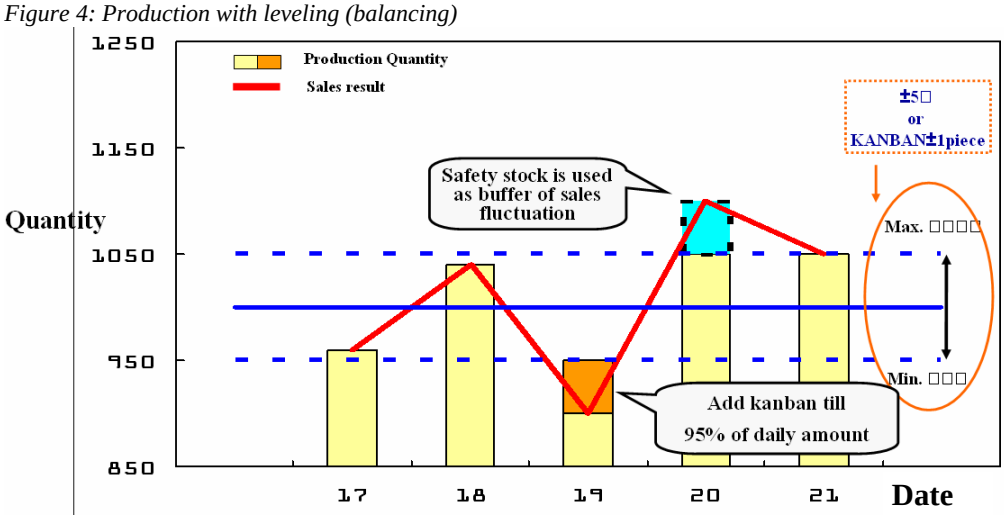



*Figure 4: Production with leveling (balancing)*




**Safety stock concept**
In the described model a safety stock is considered as a buffer for following stochastic events:

1) Volume over production capacities in current period
2) Variations of customer forecasts (from last period) = external event
3) Production line breakdown = internal events
4) Production line recovery lead-time after any breakdown = internal event
5) Lack of human resources = internal events

Pure JIT without safety stock can be operated in a company which does not face the above described stochastic events.

**Practical application**

The model of pull system described above can be used in any type of repetitive production. Its'efficiency can be found even more in long type of production. Example will be a production of aluminum housings for electric power steering in automotive. First process of production is aluminum high pressure die casting; second (final) process is aluminum housing machining. From a big lot production as first process (die casting) to small lot production as last process (machining).

*Figure 5: Production pattern evaluation*

| | | | general parameters | | | sorting costs | | | | | cost [CZK] change over cost | | | cost of line non production | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
| # | optimum calculation of 1 week pattern of 1 production line | formula | product unit cost | time (min) | quantity | 1 piece sorting time [s] | rejection probability | rejection ratio (NG ratio) [%] | labour cost [CZK/hour] | total | tooling | labour (per hour) | total | nonproduction time [min] | labour costs [CZK/hour] | total | grand total |
| 1 | Changeovers | K1 = C1*I1+B1/60*C1*J1<br>L1 = B1*C1<br>N1 = L1*M1<br>O1 = H1+K1+N1 | 150 | 15 | 10 | | | | | | 50 | 150 | 875 | 150 | 700 | 105000 | 105875 |
| 2 | Not good adjustment products (changeover products) | K2 = A2*C1*C2 | 150 | 15 | 3 | | | | | | | | 4500 | | | | 4500 |
| 3 | Average operation stock level oportunity costs | C3 = (2*safety stock + production lot volume - customer order volume (within production lot time)) / 2<br>O3 = A3*C3*oportunity ratio | 150 | | 2850 | | | | | | | | | | | | 21375 |
| 4 | Operation stock not good parts (from last period rejections (sorting) | C6 = F5*E6*F6, J6=A6*C6 | 150 | | 20 | | 0,35 | 2% | | 3000 | | | | | | | 3000 |
| 5 | Operation stock sorting time (in case of problem found) | B5 = C3*D5/60*E5 | 150 | 340 | | 20 | 0,35 | 2% | 150 | 850 | | | | | | | 850 |
| | Pattern efficiency O1+O2+O3+O4+O5 | | | | | | | | | 3850 | | | 5375 | | | 105000 | 135600 |
| # | constraints | value | | | | | | | | | | | | | | | |
| 1 | First part quality confirmation = limit for changeover frequency | 60 mins | | | | | | | | | | | | | | | |
| 2 | Minimal production lot size = = limit for changeover frequency | 30 pcs | | | | | | | | | | | | | | | |



*Figure 6: Optimal safety stock calculation*

| | | | A | B | C | D | E |
|---|---|---|---|---|---|---|---|
| | | formula | time (min) | quantity | line cycle time [s] | line efficiency | safety stock |
| # | calculation for safety stock of products of 1 production line | | | | | | |
| 1 | Volume over production capacities in current period | E1 = B2 | | 1200 | 45 | 95% | 1200 |
| 2 | Variations of customer forecasts (last period) = external random event | E2 = B2 | | 300 | | | 300 |
| 3 | Production line breakdown (last period*) = internal random event | E3 = A3*60/C/D | 220 | | | | 279 |
| 4 | Production line recovery leadtime after any breakdown = internal event | E4 = A4*60/C/D | 280 | | | | 355 |
| 5 | Lack of human resources (last period*) = internal events | E5 = A5*60/C/D | 120 | 153 | | | 152 |
| | Total optimal safety stock volume | | | | | | **2286** |

**maximum from last period*
*or average + σ from last 3 period maximums (if no improve trend)*

**Conclusion**

In case a company wants to introduce pull system and does not build up the three necessary pillars in advance this may result to big misbalances in production outputs, material consumption and usage of resources which may finally collapse. Key solution point is in best production pattern which will reflect levelized production, changeover/quality confirmation and mathematical evaluation of internal/external stochastic events which should be covered by an optimal level of safety stock.

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