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MORE MATERIAL REQUIREMENT PLANNING

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More about MRP Logic

Suppose there are two products, X and Y, and the item master, BOM and gross requirement for MPS are shown in Table 1, 2 and 3, respectively.

Table 1: Item Master

Part No.	Safety Stock	Lot Size	Lead Time	Safety Time
X	150	400	1	0
Y	100	180	1	0
A	0	180	2	0
B	0	800	2	0
1	0	800	3	0
2	0	400	2	0
3	0	600	2	0

Table 2: BOM file

Parent Part No.	Component Part No.	Qty-Per
X	B	2
X	1	1
B	2	0.25
Y	A	1
Y	1	1
A	B	1
A	3	1

Table 3: Gross requirement for MPS

Period	1	2	3	4	5	6	7	8	9	10	11	12
X	100	400	300	200	100	200	300	100	100	400	300	200
Y	100	200	100	200	100	200	100	200	100	200	100	200

From BOM file, the system determines the low-level-code (LLC) as shown in table 4.

Table 4: Low Level Code

Part No.	Low-Level-Code
X	0
Y	0
A	1
B	2
1	1
2	3
3	2

The calculation sequence of MRP is in ascendant LLC. The MRP report is shown in Table 5.

Table 5a: MRP Report

P_No. =X	Past	OH=	200	LT=	1	SS=	150	AL=	0	LS=	400	ST=	0
Period	Due	1	2	3	4	5	6	7	8	9	10	11	12
Indep. D.		100	400	300	200	100	200	300	100	100	400	300	200
GR	150	250	400	300	200	100	200	300	100	100	400	300	200
SR	100	400											
POH		450	50	150	-50	250	50	150	50	350	-50	50	250
PAB		450	450	150	350	250	450	150	450	350	350	450	250
NR		0	100	0	200	0	100	0	100	0	200	100	0
PORC		0	400	0	400	0	400	0	400	0	400	400	0
POR	0	400	0	400	0	400	0	400	0	400	400	0	0

Table 5b: MRP Report

P_No. =Y	Past	OH=	180	LT=	1	SS=	100	AL=	0	LS=	180	ST=	0
Period	Due	1	2	3	4	5	6	7	8	9	10	11	12
Indep. D.		100	200	100	200	100	200	100	200	100	200	100	200
GR	-100	100	200	100	200	100	200	100	200	100	200	100	200
SR	-50	180											
POH		260	60	140	-60	20	0	80	60	140	-60	20	0
PAB		260	240	140	120	200	180	260	240	140	120	200	180
NR		0	40	0	160	80	100	20	40	0	160	80	100
PORC		0	180	0	180	180	180	180	180	0	180	180	180
POR	0	180	0	180	180	180	180	180	0	180	180	180	0

Table 5c: MRP Report

P_No.=A	Past	OH=	180	LT=	2	SS=	0	AL=	180	LS=	180	ST=	0
Period	Due	1	2	3	4	5	6	7	8	9	10	11	12
Indep. D.													
GR	0	180	0	180	180	180	180	180	0	180	180	180	0
SR	0	180											
POH		0	0	-180	-180	-180	-180	-180	0	-180	-180	-180	0
PAB		0	0	0	0	0	0	0	0	0	0	0	0
NR		0	0	180	180	180	180	180	0	180	180	180	0
PORC		0	0	180	180	180	180	180	0	180	180	180	0
POR	0	180	180	180	180	180	0	180	180	180	0	0	0

Table 5d: MRP Report

P_No.=1	Past	OH=	500	LT=	3	SS=	0	AL=	50	LS=	800	ST=	0
Period	Due	1	2	3	4	5	6	7	8	9	10	11	12
Indep. D.		10	10	10	10	10	10	10	10	10	10	10	10
GR	300	890	10	590	190	590	190	590	10	590	590	190	10
SR	-200	800											
POH		360	350	-240	370	-220	390	-200	590	0	-590	20	10
PAB		360	350	560	370	580	390	600	590	0	210	20	10
NR		0	0	240	0	220	0	200	0	0	590	0	0
PORC		0	0	800	0	800	0	800	0	0	800	0	0
POR	800	0	800	0	800	0	0	800	0	0	0	0	0

Table 5e: MRP Report

P_No.=B	Past	OH=	400	LT=	2	SS=	0	AL=	100	LS=	800	ST=	0
Period	Due	1	2	3	4	5	6	7	8	9	10	11	12
Indep. D.													
GR	250	1230	180	980	180	980	0	980	180	980	800	0	0
SR	100	800	800										
POH		-30	1390	410	230	-750	50	-930	-180	-360	-360	440	440
PAB		770	1390	410	230	50	50	0	620	440	440	440	440
NR		30	0	0	0	750	0	930	180	360	360	0	0
PORC		800	0	0	0	800	0	930	800	800	800	0	0
POR	800	0	0	800	0	930	800	800	800	0	0	0	0

Table 5f: MRP Report

P_No. =3	Past	OH=	100	LT=	2	SS=	0	AL=	600	LS=	600	ST=	0
Period	Due	1	2	3	4	5	6	7	8	9	10	11	12
Indep. D.													
GR	0	180	180	180	180	180	0	180	180	180	0	0	0
SR	0	600											
POH		-80	340	160	-20	400	400	220	40	-140	460	460	460
PAB		520	340	160	580	400	400	220	40	460	460	460	460
NR		80	0	0	20	0	0	0	0	140	0	0	0
PORC		600	0	0	600	0	0	0	0	600	0	0	0
POR	600	0	600	0	0	0	0	600	0	0	0	0	0

Table 5g: MRP Report

P_No. =2	Past	OH=	200	LT=	2	SS=	0	AL=	0	LS=	400	ST=	0
Period	Due	1	2	3	4	5	6	7	8	9	10	11	12
Indep. D.													
GR	200	200	0	200	0	232.5	200	200	200	0	0	0	0
SR	0	400											
POH		400	400	200	200	-32.5	167.5	-32.5	167.5	167.5	167.5	167.5	167.5
PAB		400	400	200	200	367.5	167.5	367.5	167.5	167.5	167.5	167.5	167.5
NR		0	0	0	0	32.5	0	32.5	0	0	0	0	0
PORC		0	0	0	0	400	0	400	0	0	0	0	0
POR	0	0	0	400	0	400	0	0	0	0	0	0	0

In the above MRP tables, allocation, safety time, past due, projected on hand (POH), and projected available balance (PAB), require further explanation.

- *Allocation*

  Allocation shows the quantities of items that have been assigned a specific order but

have not yet been sent from the stockroom to production. When a planned shop order and its accompanying picking order for a manufacturing item is released by the planner, MRP places the released order quantity (which may or may not be the same as the planned order quantity) in the completion time-bucket as a scheduled receipt. The required components are then shown as "allocated" in each component record. There is a time lag between order release and physical component disbursement. The physical disbursement of the components reduces both the on-hand and allocated inventories by the same amount. The components allocated to a released order are treated as unavailable and are deducted from the on-hand inventory to avoid distortion of inventory status.

- *Safety time*

  Safety time is an element of time added to normal lead time to protect against fluctuations in lead time so that an order can be completed before its real need date. When the lead times are longer, the planned order releases are earlier, but the planned order receipts remain the same. Therefore, even if lead times are made longer to compensate for a supplier that tends to deliver materials late, orders will still be filled late, because although the orders are released earlier the due dates remain unchanged. Safety time changes not only order release dates but also due dates. If we use safety times instead of longer lead times, the MRP system will plan both planned order releases and planned order receipts for earlier dates.

- *Past Due*

  As MRP updates items' material requirement files, any remaining contents of buckets representing the period just passed are dropped into the past-due columns. These fields are indicators of poor performance**.** A positive value for gross requirement in the past-due column represents delinquent performance, i.e. customers originally scheduled to be delivered earlier than current date. It is a back order, and is considered urgent. A negative gross requirement in the past-due column represents excessive performance and has already been deducted from the on-hand quantity**.** Positive values for scheduled receipts in the past-due column indicate tardiness of the suppliers. In this case, records should be re-balanced and the inter-level equilibrium should be restored. Negative scheduled receipts in the past-due column represent excessive quantities received. Positive planned-order releases in the past-due column represent urgent replenishment needs. Negative planned-order releases in the past-due column represent excessive quantities released. Negative values for gross requirements,

scheduled receipts, and planned order releases in the past-due column can be ignored.

- *Projected on-hand*

  For the first period, projected on-hand inventory (POH) equals on-hand inventory (OH) plus scheduled receipts (SR) in period 1 plus past-due scheduled receipts. And, allocation and gross requirement (GR) should be subtracted from POH as well. This is shown in Table 5.

  POH(1) = OH + SR(1) + max{SR(past-due),0} – allocation - GR(1), and
  GR(1) = GR by POR of parent + Independent demand
  + max{GR(past-due),0}.

  For the other periods, the projected on-hand in period t is

  POH(t) = PAB(t-1) + SR(t) – GR(t).

  Projected available balance (PAB) will be defined later. Projected on-hand balance is used to determine whether there is a net requirement in a particular period. If the projected on-hand balance is less than the safety stock, the net requirement equals the difference between the two. As shown in Table 18, the net requirement NR(t) is

  IF POH(t)>=SS THEN NR(t)=0 ELSE NR(t) = SS - POH(t).

- *Planned order receipt*

  Planned order receipt is the quantity of materials expected to receive on a future date. It is the net requirement quantity adjusted by the lot-sizing rule and safety time. The planned order receipts differ from the scheduled receipts in that the former has not been released. In Table 5, the lot-sizing rule is the minimum order quantity LS, planned order receipts are

  PORC(t) = max{NR(t+ST), LS} if NR(t+ST)>0,
  PORC(t)=0 if NR(t+ST)=0.

- *Planned order release*

  Planned order releases are the planned order receipts after adjustment for lead-times. In Table 5, if LT is the lead-time,

POR(t) = PORC(t - LT).

Planned orders at one level are expanded into the gross requirements for components at the next level. When a planned order is released, the corresponding planned order receipt is changed into a scheduled receipt. Both planned orders and released orders are used in calculating the capacity requirements of work centers in each period in the planning horizon.

- *Projected available balance*

  Projected available balance is a projection of future inventory balance. It is the projected on-hand balance plus the planned order receipt. In Table 5,

  PAB(t) = POH(t) + PORC(t).

- *MRP Logic*

  The following is an algorithm for MRP logic:

```
PROCEDURE MRP_Logic;
BOM explosion for POR_t of MPS items and add to GR_t of components;
LLC←1;
WHILE there exists any item not processed DO
  WHILE there exists any item of current LLC not processed DO
    PAB_0←OH-AL; {SR_0>0 has been re-balanced}
    FOR t=1 TO T DO
      IF t=1 THEN POH_1← PAB_0+SR_1-GR_1-max(GR_0, 0)
        ELSE POH_t← PAB_t-1+SR_t-GR_t;
      IF POH_t<SS
        THEN NR_t← SS - POH_t; PORCPT_t← Lotsizing(POH_t, NR_t, GR_t );
        ELSE NR_t← 0; PORCPT_t← 0 ;
      ENDIF;
      PAB_t←POH_t + PORCPT_t ;
      POR_t-LT←PORCPT_t ;
      BOM explosion for POR_t-LT and add to GR_t of components ;
    ENDFOR;
```

```
      Print MRP report for current item;
    ENDWHILE;
    LLC←LLC+1;
  ENDWHILE;
  ENDPROCEDURE.
```

Nervousness in MRP

Because of the level by level expansion and lot-sizing rule of the MRP procedure, minor changes in higher level schedules cause significant changes in lower level schedules. For example, a minor change in MPS will cause significant timing or quantity changes for a material at level 5 or 6. If a system is constantly generating wildly different schedules, its credibility will suffer. The causes of MRP nervousness include changes in MPS, late supplier deliveries, poor material quality, record errors, unplanned transactions, etc… Managerial approaches to reducing MRP nervousness include seeking better communication with customers, better relationships with suppliers, and a better data processing discipline. In MRP systems, pegging and firm planned orders are frequently used to reduce MRP nervousness.

- *Pegging*

  The contents of gross requirements buckets represent the total requirements derived from an item's parents and from additional external sources of demand, and are summarized by period. The sources of gross requirements are obscure. Pegging is a procedure in the MRP system, which saves information such as period, quantity, external orders and the identity of the parent from which a planned-order release is derived in a peg file. The pegged-requirements file permits the inventory planner to trace upwards, level by level, the product structure to determine which parents generate what portion of an item's total gross requirements in any given period. A planner can use pegging to trace the demands to their ultimate sources, specific buckets for individual end items in the master production schedule. A where-used report lists all parents of a component item. A pegged requirements file, which may be thought of as a selective where-used file, lists only those parents that have planned orders in the planning horizon. A where-used report lists all parents of "one unit" of a component; a peg file lists the required quantities of the parents.

- *Firm planned order (FPO)*

An MRP program is executed periodically. In each execution, MRP reschedules the planned orders and causes nervousness. Firm planned orders suppress this nervousness by overriding the computer-driven changes. When a planned order is defined as a FPO, i.e., it is frozen in quantity and time, the computer is not allowed to change it automatically. This is the responsibility of the planner in charge of the item that is being planned. The FPO may result in a PAB less than the safety stock. By using pegging to determine which customer orders are affected, planners can decide whether to expedite shop orders or purchase orders, or postpone customer orders. FPO can help planners working with MRP systems to respond to material and capacity problems by firming up selected planned orders. FPO should be used judiciously for a few specific planned orders only rather than for an item's entire planned-order release schedule.

If the planned order releases of X in period 1 and 3 are defined as firm planned orders, in the next run of MRP, they are either switched into scheduled receipts at the same timing and quantity, or kept in planned order releases without changes in timing and quantity. Firm planned orders are indicated with asterisks as shown in Table 6.

Table 6: Firm Planned Orders

P_No. =X	Past	OH= 200		LT= 1		SS= 150		AL= 0		LS= 400		ST= 0	
Period	Due	1	2	3	4	5	6	7	8	9	10	11	12
Indep. D.		100	400	300	200	100	200	300	100	100	400	300	200
GR	150	250	400	300	200	100	200	300	100	100	400	300	200
SR	100	400											
POH		450	50	150	-50	250	50	150	50	350	-50	50	250
PAB		450	450	150	350	250	450	150	450	350	350	450	250
NR		0	100	0	200	0	100	0	100	0	200	100	0
PORC		0	400	0	400	0	400	0	400	0	400	400	0
POR	0	*400	*0	*400	*0	400	0	400	0	400	400	0	0

Suppose the planned order releases from period 1 to period 4 are defined as firm planned orders, that is, the planned order receipts from period 1 to period 5 are fixed, and the independent demands in period 5 and 6 are rescheduled to period 4. The new MRP report of X in the next run is shown in Table 7.

Table 7: New MRP Report with FPO

P_No. =X	Past	OH=	450	LT=	1	SS=	150	AL=	0	LS=	400	ST=	0
Period	Due	2	3	4	5	6	7	8	9	10	11	12	13
Indep. D.		400	300	500	0	0	300	100	100	400	300	200	200
GR		400	300	500	0	0	300	100	100	400	300	200	200
SR		400											
POH		450	150	-350	50	50	150	50	350	-50	50	250	250
PAB		450	150	**50**	**50**	450	150	450	350	350	450	250	250
NR		0	0	500	100	100	0	100	0	200	100	0	0
PORC		0	0	400	0	400	0	400	0	400	400	0	0
POR		*0	*400	*0	400	0	400	0	400	400	0	0	0

The fluctuations of independent demands do not cause any change for the POR of end product X and all the descending items. The projected available balances in period 4 and 5 are below the safety stock, which should be evaluated by the planner in order to determine whether further actions are necessary. If firm planned orders are not applied, the MRP report of X in the next run is as shown in Table 8.

Table 8: New MRP Report without FPO

P_No. =X	Past	OH=	450	LT=	1	SS=	150	AL=	0	LS=	400	ST=	0
Period	Due	2	3	4	5	6	7	8	9	10	11	12	13
Indep. D.		400	300	500	0	0	300	100	100	400	300	200	200
GR		400	300	500	0	0	300	100	100	400	300	200	200
SR		400											
POH		450	150	-350	150	150	-150	150	50	50	150	-50	150
PAB		450	150	150	150	150	250	150	450	450	150	350	150
NR		0	0	500	0	0	300	0	100	100	0	200	0
PORC		0	0	500	0	0	400	0	400	400	0	400	0
POR		0	**500**	0	**0**	**400**	**0**	**400**	400	0	0	0	0

The quantity of original POR of X in period 3 is changed from 400 to 500, as well as the planned order releases in period 5, 6, 7, 8,and 10. These changes bring severe fluctuations in the descending items.

- *Comparison of PORC, FPO, and SR*

  Planned order receipts, firm planned orders, and scheduled receipts are all material replenishment schedules. They differ in their flexibility. A scheduled receipt is a released order and difficult to change. A firm planned order has not been released, but

can only be changed by the planners. A planned order receipt is automatically changed by the MRP system. Both POR and FPO are expanded to lower levels, but scheduled receipts are not expanded further. The computer reschedules the PORC automatically but does not generate exception reports even if planned order receipts/releases are changed. In the case of firm planned orders, the projected available balances may be less than safety stock or even be a negative number, and the MRP system generates exception messages. The scheduled receipts are not changed, but if they become inadequate because of variation in gross requirements, the MRP system generates exception reports. For firm planned orders and scheduled receipts, the planners control the order release dates, due dates, and quantities. The start dates, need dates and order quantities of the planned order receipts/releases are determined by the computer automatically. Table 9 summarizes the comparison of the planned orders, firm planned orders, and scheduled receipts.

Table 9: Comparison of POR, FPO, and SR

Properties	PORC	FPO	SR
Rescheduled automatically?	Y	N	N
Exploded to lower levels?	Y	Y	N
Exception messages generated?	N	Y	Y
User control of release/receipt dates and quantities?	N	Y	Y

Regeneration and Net Change

There are two ways of using MRP systems: regeneration and net change. The differences between regeneration and net change are the data fed into the system, the retention of MRP results, and the frequency of execution.

- *The input data*

  The input data for the regeneration MRP program includes the entire contents of the master production schedule file, bill of material file, on-hand and open order inventory status, and item master records of all MRP items. For net change MRP, only changes in the master production schedule, the bill of material, and the on-hand and open order inventory status are fed into the MRP system. For instance, customer order revisions, supplier delivery date changes, defects in on-hand inventory, and BOM changes caused by an engineering change or special customer needs are all input data for a net change MRP program.

- *The retention of MRP results*

  A regeneration MRP program regenerates a completely new MRP report in each run. The previous MRP reports are not used by the system. The MRP generates reports according to the input data at run time. In contrast, a net change MRP system continually retains previous reports, and updates them with the result of MRP when updated data is fed into the system. One drawback of the net change MRP is that, because prior results are retained in the system, errors are inherited by each subsequent run. When the number of errors is no longer tolerable, the regeneration MRP program is executed to eliminate the errors.

- *The frequency of execution*

  The re-planning frequency of net change MRP is more frequent than that of regeneration MRP. Regeneration MRP is generally executed weekly while net change MRP is re-planned daily or real-time, when triggered by transactions. Because the process time is much shorter for net change MRP, its re-planning frequency can be higher. However, since only the change data is processed, net change MRP cannot purge the errors as regeneration MRP does.

Changes in Net Change MRP

The changes considered by net change MRP include changes in gross requirements (including end products, service parts, or dependent demand items), on-hand inventory, scheduled receipts, and BOM.

- *Changes in gross requirement*

  As MPS is a rolling schedule, each new period rolls in when the first period in the previous MRP rolls out. A non-zero demand in the last period is always a change of gross requirement in MPS. When customer orders are changed or forecasts are revised, the gross requirements in MPS change**.** Because of the lot sizing rule, a gross requirement change in an MPS item does not always bring a change in its planned order release. If MPS changes, the gross requirements of the MPS items' components also change. The components' planned order releases may or may not change, depending on the results of lot-sizing rule. Changes in independent demand items such as service parts are processed in the same way. Since the MRP results prior to the

changes remain the same, another MRP calculation is not required. In conclusion, the changes in gross requirements of MPS, service parts, or dependent items are processed with the MRP logic, in the sequence of the low-level code, and from the period of the first change.

- *Changes in on-hand status and scheduled receipts*

  Normal transactions of inventory status, such as the issuance of materials to feed a shop order, or the transformation of planned order receipts into scheduled receipts, are not considered net changes. Abnormal changes such as adjustments for defects found in on-hand stock, a delay in delivery from suppliers, an unexpected change in the order quantities from suppliers, etc, are considered to be changes in net change MRP. If on-hand inventory status changes, the item and its descendants, whose gross requirements are affected, undergo processing for the whole planning horizon. If the scheduled receipts change, the item and its descendants, whose gross requirements are affected, are processed from the first SR change.

- *Changes of BOM*

  If the BOM of an item is changed, the net change MRP processes that item and all of its descendants whose gross requirements are affected, for the whole planning horizon.

Net change MRP can either be executed in daily batch or whenever a change occurs. If executed in a daily batch, all the change data in a day must be collected before the execution of MRP. If a real time process is employed, then change triggers the MRP execution. The results of the net change MRP are used to update the previous MRP reports.

Comparison of Regeneration and Net Change

The comparison of regeneration and net change MRP is listed as following:

- *Regeneration*

1. Time-triggered, periodically.
2. All MPS items are expanded.
3. Every active BOM is utilized.
4. Inventory and order status of every item is recomputed.

5. Low-frequency re-planning, weekly batch
6. Self-purges errors from file.
7. Data processing is relatively efficient.
8. Voluminous output is generated.

- *Net Change*

1. Transaction-triggered, continuously.
2. Changed MPS items are expanded.
3. Partial BOM is utilized.
4. Only inventory transaction related items are recomputed.
5. High-frequency re-planning, daily batch or on-line real time
6. Keeps MRP continually up-to-date.
6. Minimizes the requirements planning job after MPS revision.
7. Requires stricter disciplines.

The Activities generated by MRP

The system categorizes MRP results according to the sources of the materials, including purchasing, subcontracting, manufacturing, and transferring.

- *Purchase requisition*

  Purchase requisition is an authority given to the purchasing department to purchase specified materials in specified quantities within a specified time. (Apics, 1995) The requisition department specifies a date and the planned order releases, which are summarized in a purchase requisition suggestion report. The purchase requisitions in the past-due period are indicated as urgent. After reviewing the purchase requisition suggestion report, the users revise and confirm the purchase requisition data.

- *Purchase order*

  Purchase requisitions become purchase orders after the purchasing department reviews and revises the quantities, due dates, and suppliers. The users use the purchase order suggestion report in order to determine which purchase orders to make. Prices and other terms of the default suppliers are retrieved from the supplier-price file in the database. If the users decide to change suppliers, they must change the default suppliers in the supplier-price file first, and then go back to the purchase order suggestion. After reviewing the purchase order suggestion report, the users revise and

confirm the purchase order data. The system then prints out the purchase orders or sends out the purchase orders through fax or email.

- *Subcontracting order*
  A subcontracting order is an order for sending production work outside to a subcontractor. It is an authority to the subcontractors to produce specified parts in specified quantities within a specified period of time. It is similar to the purchasing procedure except that there is a material issue process. In a material issue process, the system generates a picking order for each subcontracting order with shortage messages for the different components.

- *Manufacturing order*
  A manufacturing order, or shop order, is a document conveying authority to manufacture specified parts or products in specified quantities within a specified period of time (Apics, 1995). Manufacturing departments use the manufacturing suggestion reports to determine shop orders for the planned order releases. The manufacturing suggestion reports are sorted by the manufacturing departments and the plan dates. Material picking order information is generated as in subcontracting.

- *Transferring order*
  A transfer order is a document conveying authority to transfer specified parts in specified quantities at a specified time from one segment of an organization to another segment within the same organization. The MRP system generates transfer-in suggestions for the departments who need the materials from other departments, and transfer-out suggestions for the departments who provide the materials for other departments.

- *Action report*
  An action report is a rescheduling notice. Action messages include: canceling of an order, moving the due date of an order forwards or backwards, and increasing or decreasing the quantity of an order.

- *Exception report*
  MRP systems generate exception reports containing the following information: shop calendar data not exists, part number not exists, without information for supplier or subcontractor, negative inventory, lack standard times for manufactured items, lack

bills of material for manufactured or subcontracted items, exceed maximal order quantity, etc.

MRP Logic for Dynamic Environment

The standard material requirement planning (MRP) logic can be divided into three parts: netting, action message (balancing), and explosion. The netting procedure starts from gross requirement (GR), considering on-hand and on-order, determining net requirement (NR), being adjusted by lot sizing rule and safety time, and then obtains planned order receipt (PORC). The action message procedure adjusts the PORC by rescheduling the scheduled receipts (SR, on-order) to have the minimal inventory: If the scheduled receipt is not used immediately, then reschedule out the order; if a scheduled receipt is after a planned order receipt, then reschedule it in and create a new PORC if necessary. The standard MRP gathers all the requirements from sales orders or parent parts, and do the netting and action message procedures in a time phased order point (TPOP) table for each item in the sequence of low-level code (LLC). The PORC are exploded with the bill of material (BOM) to obtain the GR for the children items.

In standard MRP, the requirements in a period are combined, and because of the lot sizing rules, a PORC does not relate directly to a sales order. This is fine for make to stock (MTS) industry or make to order (MTO) industry with standard product specifications where inventory can be consumed soon, but not for MTO industry where customers specify and change the product specifications and the order due dates frequently. In the latter case, the manufacturers are demanded to quickly response to the customers the impact of the delivery for the finished goods, manufacturing for the semi-finished goods, and procurement for the raw materials related to a specific customer order change. The original equipment manufacturer (OEM) industries in Asia are typical examples of this dynamic environment.

To achieve quick response, MRP logic has to be modified. Due to the frequent engineering change on order dependent parts, an item number may represent some similar items in various orders, for establishing unique item numbers and BOM would be too time consuming. These items are called order specific items, in contrast to standard items. Since the GR of an item in a period cannot be combined, the MRP netting procedure must be vertical, going top down through a product tree instead going horizontally through a TPOP

table of an item as in the standard MRP netting procedure. It can also use horizontal TPOP but is done only for one GR. That is, each order specific item has a TPOP with only one GR. The order specific items must appear in the higher levels of the product structure, and the standard items must appear in the lower levels. The safety stock of the order specific items should be zero and the lot-sizing rule should be LFL as no further requirements are expected. However, to cope with the quality problem, the yield can be set smaller than 100%, and an adequate safety time can be chosen to compensate the lateness of the delivery. Leftovers must be processed manually and carefully. Inventory should be controlled according to the sales orders. The suppliers of the order specific items must achieve zero defects and on time delivery.

The MRP procedure starts with order specific items then standard items, the highest level of the standard items are called push-pull boundary. In the execution phase, order specific items are pulled by the orders, and the standard items are pushed by the forecast and consider the safety stock and lot sizing rules. Safety stocks are determined by the lead times and the standard deviations of the daily demands; the lot sizing rules (FOQ or POQ) are calculated by the forecasted demand rates. The order specific items are supposed to be without inventory. Rolling kanbans can be applied to regulate the material flow of the order specific items from the suppliers directly to the workstations of the production lines.

There is another category of items, which are standard (one part number for one item) but the GR and the PORC from different customer orders are not combined, though lot-sizing rules (FOQ) might cause some inventories. We called these “order standard items”. In terms of the number of requirements appearing in the planning horizon, it is one for the order specific items and the order standard items, and many for the standard items or common parts. The attributes of these items are summarized in the following table:

Category	GR or NR combination	OH and SR counted	Lot Sizing Rule	Action Message	TPOP	Number of GR
Order specific items	no	no	LFL*	Yes	One for each order item (V)	one
Order standard items	no	yes	LFL**	Yes	One for each order item (V)	one
Standard items (common parts)	yes	yes	LFL, FOQ, POQ	Yes	One for each item from all orders (H)	many

* Without multiplier and minimum quantity

** With multiplier and minimum quantity

We now discuss the vertical MRP procedure for the order specific items and order standard items.

- *Order Specific Items*

Several orders are scheduled and rescheduled in a batch. For order specific items, the insertion of an order starts with the netting of the highest level item. On-hand and scheduled receipt are not considered in the netting procedure. The algorithm to calculating the net requirement for item i in period t is:

NR(i,t) := GR(i,t); PORC(i,t) := NR(i,t); POR(t-LT) := PORC(t);

The PORC, SS, OH, SR are all 0 for the order specific items. The POR are exploded to obtain the GR of the children items.

To delete a requirement of an order specific item, GR, NR, PORC, and POR are eliminated, and related SR are indicated in the action message. To change a requirement of an order specific item is equivalent to delete the old then insert the new, and related SR reschedules are specified in the action message.

If each order specific item has a unique part number, the standard MRP procedure can be applied.

- *Order Standard Items*

The order standard items are actually standard items just the gross requirements are not combined. On-hand and scheduled receipt are considered in the netting procedure, as well as the projected available balance (PAB). (On-hand and scheduled receipt are implicitly considered in the PAB.)

Since the GR of order standard items are not combined, there is only one GR in the planning horizon. It is more efficient to calculate individual NR vertically, instead of going through the whole TPOP table horizontally. The priorities of the SO to be scheduled are determined first, then each item's NR is calculated according to the sequence of priorities. The earlier (or higher priority for the same period) GR consumes (allocates) the unallocated OH and SR first, (OH and SR must be leftovers from past SO) the NR, PORC and POR are determined, and the GR of children in the next level are calculated. Every

PORC is related to a specific SO. When the PORC of an item is determined, they are compared with all the allocated OH and SR to adjust the allocation, i.e., reassign the SO attached to OH, SR and PORC. It is a change of priority: Some OH or SR allocated for a SO may be moved to feed another SO, and the original SO has to generate PORC to meet the demand, and the PORC for the lower level items are recommended accordingly. It is actually a net-change MRP procedure, only the changed independent demands are scheduled. The independent demand is divided into two parts: is-scheduled and to-be-scheduled. The above procedure schedules the to-be-schedule part first, then reconcile the result with that of the is-schedule part. Therefore, the is-scheduled part demands could be rescheduled. One SO number is attached to each OH, SR and PORC. If an old SO is cancelled, all the related OH are released, SR cancelled, and PORC ignored. If the quantity of an old SO is changed, the change of the quantity of the related SR and PORC are calculated. If the due date of an old SO is changed, the system deletes it then inserts a new one. The reconciliation function can be disabled for a specific item of a SO to cope with the situation when no new item number is assigned to an engineering-changed item. In that case, items of the same number are not changeable. It is actually identical to the case of order specific items.

The sequence of LLC must be followed for there may be standard items beneath the order specific items or order standard items. Since there is no order specific or order standard items under standard items, the vertical netting procedures can be executed before the horizontal netting procedures of the stand items are started. In executing vertical netting procedure, LLC controls the sequence of the netting of the items for a customer order.

When a requirement of an order standard item is deleted, the related PORC are removed and the SR are rebalanced top down. To change an order is to remove the old and insert the new. The vertical MRP procedure is similar to a net-change MRP procedure.

In conclusion, order specific and order standard items must be identified for MRP to decide if it should combine the GR of the items with the same item numbers. A pegging code should be assigned to each requirement related to an order. OH and SR leftovers released by past orders are considered for order standard item. MRP processes order specific and order standard items before processing standard items. Since there is only one GR in the TPOP for order specific and order standard items, MRP logic should be simplified to enhance the efficiency.

Action Message

The most important output of MRP is the action message. Users may look up the MRP calculation tables (TPOP) to obtain more information, but they take actions according to the action messages. MRP action message includes the followings:

1. If there is a FPO in a period and the PAB at the end of the period is lower than SS, then the message is “Increase the quantity of FPO”.
2. If there are both PORC and SR in a period, then the message is “Increase the quantity of SR by the amount of PORC”.
3. If a PORC occurs before a SR with a quantity larger than SR, the action message is “Reschedule in the SR and increase its quantity by the amount of PORC”.
4. If a PORC occurs before a SR with a quantity smaller than SR, the action message is “Reschedule in the SR and reduce its quantity”.
5. If the PAB at the end of the period of a SR is larger than SS, then the SR is postponed to the period, say x, in which the PAB will be firstly below SS. The action message is “Reschedule out the SR to period x”.
6. In the above situation, if the PAB is larger than SS even when the SR is scheduled to the end of the planning horizon, the action message is “Cancel the SR”.
7. If positive SR occurs in the “overdue” period, then the message is “The SR is overdue, finish it as soon as possible”.
8. If PORC occurs in the “overdue” period, then the message is “Emergent order”.

Action messages are processed in the sequence of time instead of parts. The earlier actions are taken first. If an action cannot be taken, then users should refer to the pegging message to trace back and adjust the delivery dates of relevant orders, level by level, and ultimately to the customer orders. Single-level pegging messages can be accessed from the MRP system. Human judgment is important for firming, releasing an order and for tracing back a requirement.

Time-phased Allocation

In collaborated or centralized MRP of a supply chain, “material allocation” is the key to coordination among the companies. We now describe the concept for allocation and supply

chain MRP.

A “planned order” includes a POR and a PORC; a “firm planned order” (FPO) includes a firm POR and a firm PORC; a “scheduled order” includes a scheduled release and a scheduled receipt (SR). That is, an order - planned order, firm planned order, scheduled order, whatever it is, must have a release date and a receipt date. When we are sure that a planned order will be executed, we firm it or release it.

There are two reasons that we firm a planned order. The first is to reduce the nervousness of MRP, and the second is to rush orders. We don’t want the MRP to reschedule the near planned orders for that would bring troubles of adjusting related low-level-material orders which might have been started, so we firm them to decrease the nervousness of MRP. If a supplier informs us that a material will not be on schedule, and the assembly of the end product will be forced to start 3 days later. Since the customer will not allow us to deliver the products late, we check the supervisor of the assembly line and he promises to rush the order and reduce the lead-time by 3 days. Then we firm the planned order, i.e., we fix the PORC of the related assembly jobs. The time and quantity of these firm planned orders will not be changed in the next MRP run.

When we require something, we have a demand. If something is available, or we are sure something will be available, we have a supply. MRP is to balance the demand and supply. Therefore, gross requirements including allocations from the higher-level scheduled orders are demands, and on-hand and scheduled orders are supply. Remember, a supply is what is we are sure will be available. If the supply is less than the demand, orders are planned. Thus, the results of MRP balancing are planned orders. Since demands are fluctuate, one must not firm or release a planned order too soon without care.

A planned order can be firmed, before released, to reduce the nervousness of the MRP, or firmed even earlier when a rush order is confirmed. To firm an order is to fix or anchor it; to release an order is to execute it. Releasing a planned order results in a scheduled receipt, which reduces the POR/PORC of the parent and its requirement of the components. We need to allocate the components for the scheduled receipt at its start time, i.e. time of POR before it is transformed into SR. It is equivalent to adding the allocated quantity to the components’ GR. Therefore, the source of the demand, GR, includes requirements coming from parents’ POR and the allocations from parents’ SR. The allocated quantity is cancelled when the components are withdrawn.

In MRP, all requirements in a period are combined into GR to compute a PORC. Thus the PORC of a component comes from its parents' planned orders (MRP suggestion) including firm planned orders (orders opened not released), and scheduled orders (orders released but materials not withdrawn yet). In calculating PORC, the PAB at the end of the previous period are used to cover requirement and allocation from the parents' planned and scheduled orders. If the sum of the PAB and SR of the component fails to cover the requirement, a PORC is created when there is no firm planned order, or action messages are generated when there is.

A planned order has no order number, but a firm or scheduled order does. If the market is make-to-order and the manufacturing lead-time is short, the planned orders related to a customer order should be released at once, but not issue materials of the order-specific items till start time, for the customer order may change. The accumulation lead-time including transportation should be short. The released WO/SC related to a customer order form a tree with the final assembly WO at the root. All the planned orders of the "order specific items" related to this customer order will not show. When the customer order changes, the action message will indicate related SR changes, and the stock of the materials on the push-pull boundary will be reallocated.

When a parent's planned WO/SC is released, the requirements of the components (allocation) are added to the GR of the components. When the components are withdrawn, both the allocation, contributed by parent's SR, and the OH are reduced. Users should check the on-hand and on-order inventory status before releasing a WO/SC. If the manufacturing lead-time of a WO/SC is short or the materials are required from the beginning of WO/SC, the orders must not be released until there is enough on-hand of the components.

In a supply chain, MRP covers from the ultimate downstream to the original upstream items. The POR of the downstream item generates the GR of the upstream item. The upstream company confirms the delivery by releasing the planned orders of the order specific items. If the downstream company releases a planned order but the upstream item does not have enough SR, then the MRP in the upstream company generates an action message asking for releasing planned orders for the order-specific items. Suppose the supplier, i.e. upstream company, cannot meet the delivery date, he calls the downstream company and the latter agrees to cut its manufacturing lead-time or postpone its require

date and start later, then the buyer modifies its SR and the supplier release its planned order. When the buyer reschedules the SR, the MRP allocates the SR of the supplier. Theoretically, there is no OH inventory for order specific items.

In MRP, the released WO/SC "tree" for order specific items is considered and any attempt of changing to these SR are coordinated and shown in the action message. A change of a SO brings the changes for all the WO/SC in the tree, i.e., the action message covers the whole tree of WO/SC.

To implement the above, following changes are made to equation (2) of Appendix C in page 455 of this book:
POH(1) = OH + max(SR(0),0) + SR(1) + –AL(0) –AL(1) – max(GR(0),0) – GR(1), for t=1;
POH(t) = PAB(t-1) + SR(t) – AL(t) - GR(t); for 1<=t<=T;
The row for allocation is inserted below the GR row in the TPOP table. Note that the actual gross requirement is the sum of GR and AL.