MIT SCALE RESEARCH REPORT

The MIT Global Supply Chain and Logistics Excellence (SCALE) Network is an international alliance of leading-edge research and education centers, dedicated to the development and dissemination of global innovation in supply chain and logistics.

The Global SCALE Network allows faculty, researchers, students, and affiliated companies from all six centers around the world to pool their expertise and collaborate on projects that will create supply chain and logistics innovations with global applications.

This reprint is intended to communicate research results of innovative supply chain research completed by faculty, researchers, and students of the Global SCALE Network, thereby contributing to the greater public knowledge about supply chains.

For more information, contact
MIT Global SCALE Network

Postal Address:
Massachusetts Institute of Technology 77
Massachusetts Avenue, Cambridge, MA 02139 (USA)

Location:
Building E40, Room 267
1 Amherst St.

Access:
Tel: +1 617-253-5320
Fax: +1 617-253-4560

Email: *scale@mit.edu*
Website: *scale.mit.edu*

Research Report: ZLC-2014-5
Reduction of Total Cycle Time and Impact of Service Level on Working Capital for a Chemical Company
Arunangshu Ghatak and Chenyao Liu

For Full Thesis Version Please Contact:

Marta Romero
ZLOG Director
Zaragoza Logistics Center (ZLC) Edificio
Náyade 5, C/Bari 55 – PLAZA 50197
Zaragoza, SPAIN
Email: mromero@zlc.edu.es
Telephone: +34 976 077 605

Reduction of Total Cycle Time and Impact of Service Level on Working Capital for a Chemical Company

By Arunangshu Ghatak and Chenyao Liu.

Thesis Advisor: Professor Alejandro Serrano, Ph.D.

Summary: Our thesis proposes a model to reduce high Total Cycle Time (TCT) and thereby reduce Working Capital in a Specialty Chemicals Industry. We define the TCT for the Sponsor and based on the analysis, we propose a pull based multi-echelon inventory management system to replace the existing MRP based push system.

Arunangshu Ghatak
Master of Technology in Industrial Engineering and Management,
Bachelors of Technology (Hons.) in Manufacturing Science & Engineering
Indian Institute of Technology, Kharagpur

Branch Engineer– ITC Limited, India.

Chenyao Liu
Bachelor of Science (First Class Honors) in Applied Mathematics
National University of Singapore.

Operations Analyst, Clearing & Settlements, Equities, Investment Bank
UBS AG, Hong Kong

KEY INSIGHTS

1. Long TCT leads to higher inventories. Effort should be made to reduce TCT.
2. Push based systems should be evaluated and wherever possible, a pull based system should be implemented.

Introduction

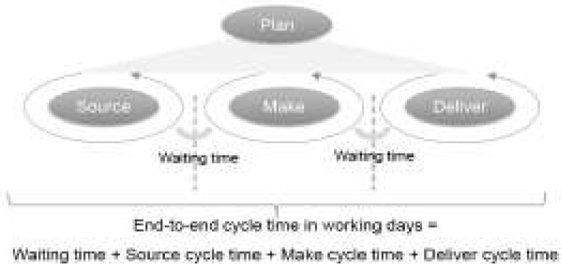
Many companies put in a lot of effort to reduce cycle time not only as a means to respond faster to customer requirements, but also to keep inventories and hence working capital lower. Our thesis is sponsored by a Specialty Chemicals company based in Europe. The Specialty Chemicals Industry is fragmented and there are many players making this sector highly competitive. In this scenario, it is important for Specialty Chemicals companies to maintain high customer service levels while reducing working capital. As per the last Annual Report the company had 700 million euros in inventories, which was approximately 10.3% of its assets, while one of its competitors, which is an industry leader, had inventory amounting to only 8.9% of the assets. The annual inventory turnover for the thesis sponsor was 4.99 compared to the competitor which has a higher annual inventory turnover of 6.03. The intention of this benchmarking was to check if maintaining a higher inventory turnover or lower inventory is possible in the specialty chemical industry, and we found that it is possible. Presently the company has a service level of 83% and it measures service level with a Key Performance Indicator (KPI) known as On Time In Full (OTIF). OTIF means that if the company is able to serve the customer on or before the day when it promised delivery of the product, it's a service success; otherwise, it's a service level failure.

In this thesis, we worked on a select group of products and its components (raw materials), evaluated the supply chain in totality and devised a useful model which can be used by the company to reduce cycle time while maintaining or improving service levels to customers. This model can be replicated to other product groups as well. The product family consists of a finished product, an intermediary, and six raw materials. These materials are defined as FG, IM, RM1, RM2, RM3, RM4, RM5 and RM6 (for the raw materials) respectively. IM is sometimes produced separately for direct sale to customers only if there is a specific customer order. These notations would be used in the rest of the executive summary.

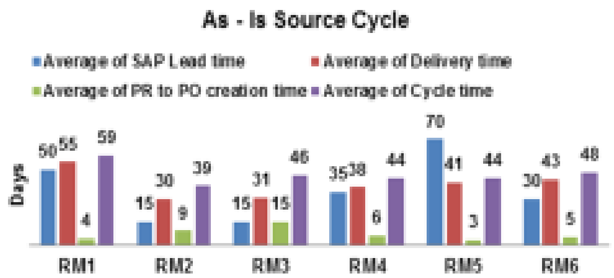
TCT Definition and As-Is Value Stream Map

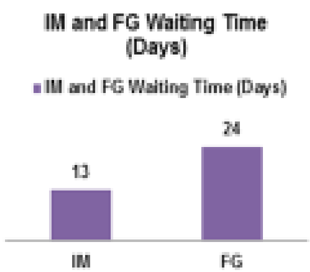
We defined the TCT based on a previous work done (Martin & Wakolbinger,2013), where the Total Cycle Time comprises all stages of the entire supply chain from raw material purchase order to the delivery of finished goods. Based on the Supply Chain

Operations Reference (SCOR) model from Supply Chain Council, the whole supply chain for all products is classified as Source, Make, and Deliver cycle process, and the total cycle time is further defined as the sum of Source, Make, and Deliver cycle time, as well as waiting time in between. We did not take into account the Plan cycle time. Each of these cycles can be determined independently. For example, the Deliver cycle is differentiated by region and customer segment since lead times vary for them.



For our thesis, we calculated TCT for the company by using the maximum cycle time for each of these cycles. We analyzed the Source, Make and Deliver cycles individually, and found out the Waiting times* of the RMs and FG in the inventory as well. We did not consider the IM in our models since IM was produced only when it was separately ordered by a customer (make to order product). When IM was produced in order to produce FG (IM is intermediary for FG), it was consumed in a few hours.



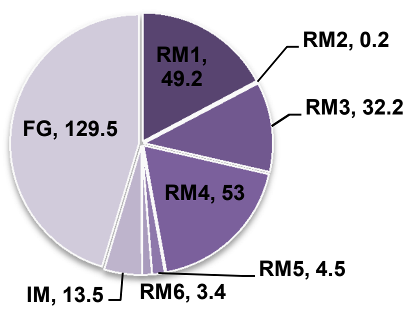


The TCT was calculated by adding the longest raw material Source cycle time + longest raw material Waiting time + Production time + products Waiting time + average Deliver cycle time. We found the TCT for FG = 172 days. However, in order for future analysis and calculation of future potential of improvement we considered the SAP Lead times for the source cycle. This is because SAP lead times were the theoretical lead times for RM delivery and was the agreed upon time by the company. Based on that, the TCT was found to be 183 days.

Deliver Cycle Time (Segmented by Countries)				
Destination country	Customers Demand Breakup	Deliver Cycle Time (Days)	Average Transportation Time (Days)	Internal Lead Time (Days)
Germany	37%	31	4	26
Hungary	18%	44	7	37
Japan	14%	91	44	47
Great Britain	10%	38	7	31
Austria	7%	32	6	26
Italy	3%	25	4	22
Belgium	3%	32	4	27
Spain	2%	19	2	16
Others	6%	41	21	21

The average on hand inventory value was 286,000 euros, but if the IM was excluded then the average inventory value was 272,000 euros. The breakup of the inventory is given in the pie chart below.

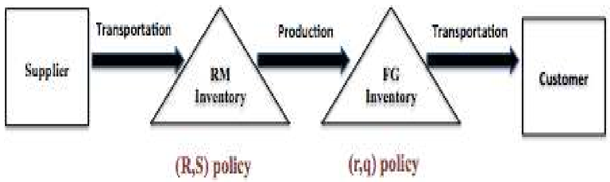
Inventory On Hand ('000 Euros)



Analytical Model

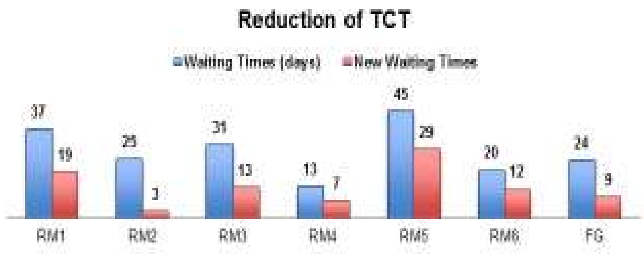
The existing inventory planning for the company is done through an MRP system, where the demand forecast of the Final Product is used to forecast the demand for the raw materials. This is a push system, which is based more on forecast rather than on actual demand; therefore, it is difficult to know when and which products will be needed. The current MAPE (forecast error) is 21%. We observed that both the FG and IM had a normally distributed monthly demand. As per Demand Planners in the company, the demand was stable, and is expected to be stable. Therefore we propose to change the forecasting based system to a pull based system. We propose a periodic review policy or (R, S) policy for raw materials replenishment and a continuous review policy or (r, q) for finish goods replenishment. Under (R, S) policy, orders are placed according to a defined review period R. At each review point, the current inventory position is checked against a predefined order up to level S (OUL). Then the difference between the current inventory position and the order up to level (OUL) is ordered to replenish the inventory at the end of every review period. The quantity ordered will replenish the inventory after an average lead-time L_k.

In our analysis, we assumed q to be one production batch size of FG (batch size of 25,000 Kg.), because of the company's internal constraint of keeping a constant production batch size. The complete analytical model for this two-inventory stage system is shown below.



Analytical Model - Results

We found that the total, assuming service level is 93% (internal company target), TCT for FG reduces by 9%, from 183 days to 166 days. The reduction is 12% if the delivery transportation times are excluded from the scope (reduction from 143 to 126 days). This reduction comes from the waiting time reduction. The waiting time reduction is shown in the figure below.



The corresponding reduction in working capital (inventory on hand) is 56%, *i.e.*, from 0.27 million euros to 0.12 million euros (excluding IM inventory), at 83% service levels, and is 41%, *i.e.*, to 0.15 million euros at 93% service levels (company target).

Simulation Model

The analytical model gives us an understanding of the reduction potential of the methodology proposed. However, it does not give us the true picture in terms of service level. Cycle Service Level (CSL) assumes that the order has to be fulfilled when the customer order arrives at the company. However, the company measures the service level in terms of a KPI known as OTIF, which takes into account, the time when the company promises delivery of the order to the customer. If the delivery happens before or on the promised date, it is an OTIF fulfillment, else it is treated as an OTIF failure. In such a scenario, the actual time of order arrival and shipment completion time has to be taken into account while modeling it. In other words, OTIF takes into account the transportation time for the order deliveries to the customer as well. In order to incorporate these concepts, a simulation model was prepared with the simulation software *Rockwell ARENA.* This software allows the creation of models that are based on a discrete event simulation over time. The software allows modeling different events that are related to the occurrence of demand or the release of an order. These events can then be linked to different variables. In the simulation, the demand of the finished products can be used to decrease the stock of finished goods from the warehouse.

Simulation Model - Results

According to the results the Total Cycle Time and Working Capital can be reduced significantly (Working Capital is reduced by 42.4%, and TCT by 9%). The simulation model can record the daily inventory levels in an Excel file. This file is used to plot the daily inventory for a period of 1,080 days assuming no change in demand pattern. The daily inventory levels have been used to arrive at the average inventory figures for the simulation model. The graphs below show the inventory levels for the raw materials, FG and Overall Inventory (FG + Raw Materials). Both models have similar reduction potential. We observe that for a review period of 14 days, the simulation model predicts a reduction potential of 42.4% as compared to the analytical model, which predicts 41.7%. The figure below gives a comparison of waiting times between the simulation and the analytical model.

Product Name	Avg. Inv. as per simulation model (Kg.)	WC as per Analytical Model (euros)	Avg. Inventory as per simulation (Kg.)	WC as per simulation (euros)
RM1	32,363	36,684	27,364	30,921
RM2	50	32	229	144
RM3	13,985	19,299	16,286	22,474
RM4	29,177	41,242	36,206	51,051
RM5	1,090	2,922	1,122	3,006
RM6	160	4,190	313	8,206
FG	39,170	54,327	29,314	40,746
TOTAL	115,994	158,694	110,834	156,550
Reduction		41.70%		42.40%

Customers by Region	OTIF Yes	OTIF No	OTIF
Non Spain EU	920	53	95%
Spain	19	0	100%
Japan	96	0	100%

The simulation model also gives the OTIF levels observed for different markets As expected, the OTIF levels are higher than the Cycle Service Level (93%) for which the model was designed. This is because for OTIF, the company has the option of making the product and sending it to the customer even if the product is not available in the inventory when the demand comes to the factory.

An estimation of savings per year was done depending on the company's Weighted Average Cost of Capital (WACC). WACC is a part of the inventory holding cost. We found that with WACC at 8%, the savings per year (euros/year) as a percentage of the total initial inventory was 3.4%. With an increasing WACC, the savings percentage also increases simultaneously to 5.94% (when WACC is 14%). The figure below gives the details of the savings per year with varying WACC. If we consider only the product family given to us (FG, IM, RM1, RM2, RM3, RM4, RM5, RM6), then the savings per year can be estimated to be 16,165 euros per year.

WACC	Savings per year (as a percent of existing Inventory)	Savings per year for[1] the product family (euro/ year)
8%	3.4	9,237
10%	4.24	11,546
12%	5.09	13,855
14%	5.94	16,165

The company has 700 million euros in Inventory. This means that if this model can be applied to all its products and raw materials, and assuming that it can be extrapolated, then we can have an estimated savings of 23.8 million euros per year if the WACC is 8% and the same can go up to 41.58 million euros per year if the WACC is 14%. Although this model may not be applicable to all product families, this model provides a direction for significant savings potential. Hence, this model can be extended to all applicable products within the company to fully realize its potential.

Implementation

The following changes would be required in case of implementation.

1. Define Reorder points and Order Up to Levels for continuous review and periodic review models in the ERP system (In this case SAP).
2. Ensure an automated MRP (Material Requirement Planning) for triggering production runs for FG.
3. Ensure automated MRP runs for RM (Raw Material) planning as well, after the end of review period.
4. Recheck the actual requirement of PR to PO (Purchase order) conversion time so that the lead times for RM delivery is kept on check.
5. Ensure a good monitoring of lead times so that there is no delays. Variations if any should be tracked and built into the model so that the reorder point and Order up to levels are automatically changed.
6. Cut off forecasting based inventory management for the pilot run.
7. Ensure periodic review of demand of the product to check if the average demand of the product is shifting or not.

Conclusion

We found that the proposed model can improve TCT by 9% and working capital by around 41%. Based on our findings we are making the following recommendations.

1. Select all products which have a stable and a normally distributed demand, and consider them for the pull based proposed model.
2. Benchmark transportation times between various transporters and with agreed times to reduce the transportation time.
3. Ensure continuous monitoring of supplier lead times and lead times should not be allowed to exceed the agreed times.
4. Ensure continuous monitoring of internal lead times (time between conversions of the purchase requisitions to purchase orders).

With the proposed pull system, the batch sizes of some raw materials would change and would reduce. This means that the new batch sizes would have to be renegotiated with the suppliers. The company can also think of pooling in orders from its other European factory for common raw materials. This would prevent the supplier from reducing its batch size of production but still can easily transport in smaller batches to individual factory. With these recommendations, it will be easier for the company to reduce its overall cycle time.