Applying Quick Response Manufacturing to Exploit Variability and Reduce Lead Time in the Job Shops

C.S.Bong, K.E.Chong

ABSTRACT: ***The connection between limit use, lead time and inconstancy is surely knew in the assembling business. The high-blend, low-volume and client built item assembling, for example, exactness parts creation is a run of the mill high-inconstancy generation framework. Some inconstancy is unavoidable in this condition, yet the capacity to adapt to it can likewise be a basic wellspring of benefit. This paper will clarify why Quick Response Manufacturing (QRM) idea is picked to adapt to the vital inconstancy that can't be dispensed with by Lean execution in the activity shops. The Queuing Theory is connected ahead of the pack time decrease approach and the outcomes are exhibited through Operating Curves with evolving Variability, Utilization and Raw Process Time. The Operating Curve demonstrates the QRM rule functions admirably by lessening limit use will in general have an a lot bigger effect on lead time than decreases in changeability. Thus, the subsequent improvement can be associated to diminishing length or potentially cost in the long haul.***

KEYWORDS: Quick Response Manufacturing, Small and Medium Enterprises, Job Shop, Variability, Lead Time.

1 . INTRODUCTION

Capacity utilization, lead time and variability within a factory are mathematically related to one another in a counter-intuitive way. The failure of many Small and Medium Enterprises (SMEs) to understand this relationship's nature has led to poor decision making about investments and manufacturing strategy. Precision parts fabricators are among the most complex products manufactured today.

The quick pace of progress in the business, in mix with the intrinsic challenges in overseeing dynamic occupation shop conditions, prompts conflicting execution. The need to manufacture an arrangement of high-blend, low-volume and specially designed items, every one of which requires an alternate measure of time or assets for generation, just make wasteful aspects after some time that outcome in money related misfortunes. These losses can come either from mismanagement of resources or by an increase in lead times as material waits in queue. Managers may be caught in vulnerable positions where they are blamed for not meeting expectations and unable to understand or explain why. Companies are often under pressure to invest in expensive and complex scheduling software when the root cause is in variability and production control mechanism.

Traditionally, lean is a famous method sought after to eliminate variability for the optimization of production, intending to level demand and balance flow within a system. However, in job shop situation, some variability is inevitable, hence the SMEs must seek other tools. Managing variability in a sophisticated fashion can have positive effects for precision parts manufacturers, creating an opportunity for them to distinguish themselves from their competitors.

From the key production characteristics of continuum [1] and comparison [2] between Lean and Quick Response Manufacturing (QRM) shown in Table 1 and Table 2 respectively, the latter concept is the preferable solution for high-mix, low-volume and custom-engineered manufacturers with the intention to exploit variability and reduce lead time in the company.

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Table 1: The Key Production Characteristics of Continuum

Favors *LEAN* implementation		Favors *QRM* implementation
Low Mix	⇔	High Mix
High Volume	⇔	Low Volume
Low Demand Variability	⇔	High Demand Variability
Low Degree of Customization	⇔	High Degree of Customization

Table 2: The Difference between LEAN and QRM

LEAN	QRM
Focuses on waste reduction	Focuses on lead time reduction
Uses KANBAN as material flow control mechanism	Uses POLCA as material flow control mechanism
Capacity Planning: Plans by using Takt time which is not meant for high-variability environments	Capacity Planning: Plans by including job variability with some spare capacity
Encourages executive team to change policy in order to eliminate waste	Encourages time-based decision making and financial justification
Eliminates all variability	Eliminates dysfunctional variability & provides competitive advantages by using QRM tools, concepts & principles

2. BACKGROUND OF THE RESEARCH

This paper is based on a case study of the whole shop floor process of a precision part manufacturing company located in Malaysia. This SME is a worldwide leading supplier specializing in fabricating machinery and tooling parts for semiconductor industries. The main strength of this SME is manufacturing highly complex parts based on the customer's specifications. The high-mix and low-volume of customer demands have resulted in jobs that require travelling in different process routes and at different process time. The typical process flow in the company is presented in Figure 1. First, process flow is planned by the technical personnel once customer order is received. A job order is created and sent for programming if it involves CNC machining operation. The job is then sent to shop floor for fabrication. Upon completion of the planned processes, the finished part is transferred to Quality Control for inspection followed by packaging and shipping to customers.

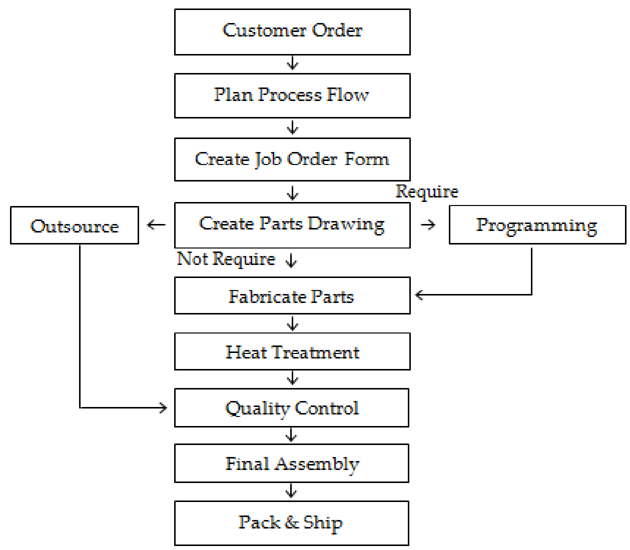

Figure 1: A typical process flow of precision part fabrication

The main challenge of such a job shop environment is to fulfill the customer order on time. The late deliveries of goods to customers had led to losses in revenue and business opportunities, which in turn, affect the image and reputation of the company. Figure 2 shows the on time delivery (OTD) records from 2013 to 2016. It clearly shows that the OTD averages are less than 55%, well below the company's target of 90% with the main contributor of the failure is due to the manufacturing lead time (LT) exceeding the committed delivery of 2 weeks to customers. Figure 3 presented the same years of performance of the exemplary product BI for the case studied company where the actual LT exceeding the target set. In the current scenario it is quite challenging to overcome the company's problem by using the well-known method such as forecasting or built-to-stock method.

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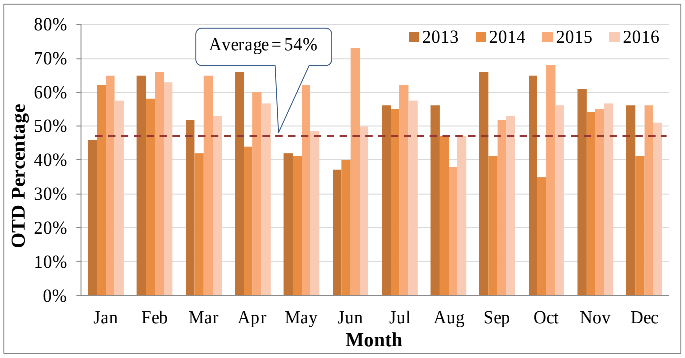

Figure 2: On time delivery from 2013 to 2016

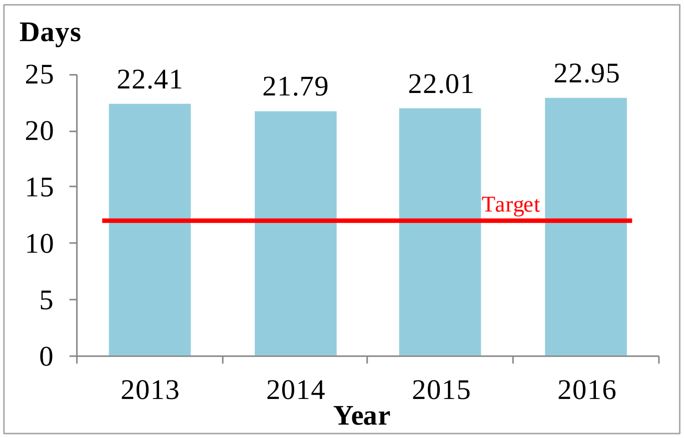

Figure 3: Lead time of exemplary Product BI from 2013 to 2016

1.0 quick RESPONSE MANUFACTURING

QRM is a more rational approach to job shops in this case study. It is able to distinguish some logical messages compared to some other common approaches [3]. Pyrek [3] stated that QRM is a method which searches new execution methods and it focuses mainly on time reduction and reserves spare capacity as the main indicator, involves suppliers and buyers in the QRM program.

1.1 Exploiting Variability

The premise of Lean are in high-volume, dull generation, and the center devices, for example, Takt Times and level planning are intended to dispense with changeability in tasks and make better stream [4]. In any case, high-blend, low-volume and customization situations present noteworthy difficulties because of the nearness of two unique kinds of fluctuation [4].

- Dysfunctional fluctuation: Errors, ineffectual frameworks that reason improve, continually evolving needs; and "uneven" request because of poor interfaces among deals and clients.

- Strategic inconstancy: This type of changeability is acquainted by an organization with contend in the market. The capacity to serve showcase with profoundly erratic interest, a vast assortment of choices for clients and offering exceptionally designed items.

While Lean strategies intend to take out inconstancy in the assembling framework, the QRM approach is lined up with Lean in disposing of broken fluctuation. Be that as it may, QRM does not wipe out vital changeability, rather it abuses it. This is finished by planning the QRM association to adequately adapt to this changeability and flourish in the high-customization markets of things to come [4]. Consequently QRM takes Lean procedure to the following dimension (Figure 4). This will turn out to be progressively vital as clients request a more extensive cluster of alternatives and modified highlights.

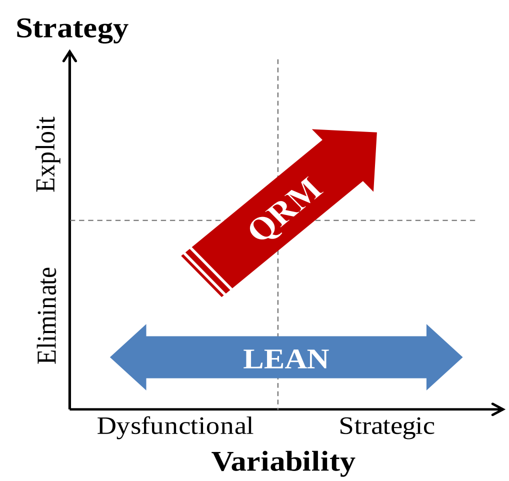

Figure 4: QRM takes Lean to the next level

1.2 Exploiting System Dynamics Principles

This center idea enables directors to see how framework elements impacts lead time. A typical administration misguided judgment is "To land positions out quick, we should keep our machines and individuals occupied constantly." [5] This doubt comes from cost-based reasoning as observed from the principal chart 5a in Figure

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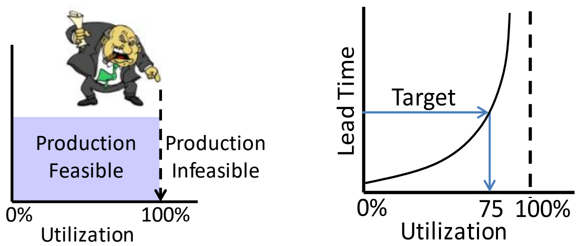
5: to guarantee every asset is utilized maximally to limit cost so you can manage with minimal number of assets [6]. So as your assets get busier, you make developing lines for employments and result long lead time with facilitating and other hierarchical expenses – the inverse of the brisk reaction standards. The QRM approach demonstrates that these broken cooperations result in framework wide costs that surpass the expense of the extra limit. The QRM rule that replaces the conventional conviction is very extraordinary, "Deliberately plan for extra limit – the arranged stacking of your assets ought to be under 85%, or even under 75% in high-changeability environments."[5]



5a. Cost-based View
5b. QRM View

Figure 5: Cost-based thinking vs. QRM system dynamics theory

QRM clarify the framework elements hypothesis, which discloses to us that lead times increment significantly as assets uses approach 100% as appeared in Figure 5 second chart 5b [6]. Since in QRM you don't kill key fluctuation, it is vital to structure your framework to adapt to some inconstancy. QRM recommends on an alternate driving measurement to improve fabricating: lead time. Defenders of this logic trust that by diminishing the time it takes to create an item from request to conveyance, all out expenses go down and quality, conveyance, and adaptability all improve

.

2.0 LEAD TIME REDUCTION APPROACH

Guideline (Queuing Delay) gives down to earth logical connections, for example, the "VUT condition" [7], where the deferral due to lining is equivalent to an inconstancy factor increase by use factor duplicate by compelling procedure time as appeared in eq. (1). An end product to the articulation in eq. (1) is the Total Cycle Time (CT) as characterized in eq. (2)

$$\text{Delay} = V \times U \times T \quad (1)$$

$$\text{Cycle Time} = VUT + T \quad (2)$$

where: V = Variability factor
U = Utilization factor
T = Raw Process Time

The primary understanding we can get from the VUT condition is that changeability and use collaborate. High inconstancy (V) will be most harming at stations with use (U), especially at bottlenecks. Along these lines, decreasing lining deferral should be possible through a blend of exercises that lower use and/or diminish fluctuation. We can draw extra experiences through the aftereffects of Operating Curve (OC) displayed in Figure 6 [8][9]. The use will be relative to u/1 – u, where u is the limit usage. This implies as use approaches 100%, CT will approach limitlessness. The fluctuation factor is an element of both landing and procedure changeability, as estimated by the CV's of interarrival and procedure times. The fluctuation is commonly corresponding to the Squared Coefficient of Variation (SCV) catching the variety of the interarrival times and the procedure times . Figure 6 demonstrates a plot of OC for three distinct dimensions of changeability: low, medium and high. A full treatment of CT (Queuing Theory) is a long ways past the extent of this paper, however at an abnormal state, the three conceivable lead time decrease methodologies can be considered as appeared Table 3.

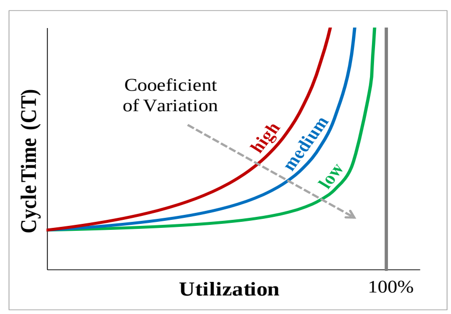


Figure 6: OC – Impact of Utilization and Variability on CT

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Table 3: Lead time reduction strategies

Factor	Variability (V)	Utilization (U)	Raw Process Time (T)
	$\left(\frac{c_a^2+c_e^2}{2}\right)$	$\left(\frac{u}{1-u}\right)$	= standard time required to process a job
Alternative solutions	Reducing variability of … • availability • setup & repair time • arrivals • etc…	Reducing utilization by… • decreasing output • increasing capacity • increasing availability • etc…	Reducing process time by… • single job processing • decreasing batch size • process improvement • etc…
Approach	LEAN to eliminate the *dysfunctional variability*	QRM to exploit the *strategic variability*	QRM / DFM to improve or redesign the process
Analysis & Discussion	Section 4.2; Figure 7 First graph		Section 4.2; Figure 7 Second graph

2.1 Manufacturing Critical-path Time (MCT)

MCT is characterized as the time caught in date-book days beginning from the client request, through the basic way, until the conveyance of the principal end-thing of that request [10]. MCT is a basic yet amazing measurement to evaluate all out framework wide misuse of an association.

The examination of this constant estimation help to distinguish which part or subset of a venture is required for development. The MCT can be outlined, best case scenario in a MCT Map [11]. Figure 7 represents a case of the MCT Map of Product BI for the situation considered organization. This guide gives a reasonable knowledge of what is happening in the diverse procedure with next to no clarification required, for instance, we can see that the HP part manufacture takes 22 days and subsequently the longest basic way. The holding up times that appeared on the guide uncovered the most elevated potential territories of lead time decrease.

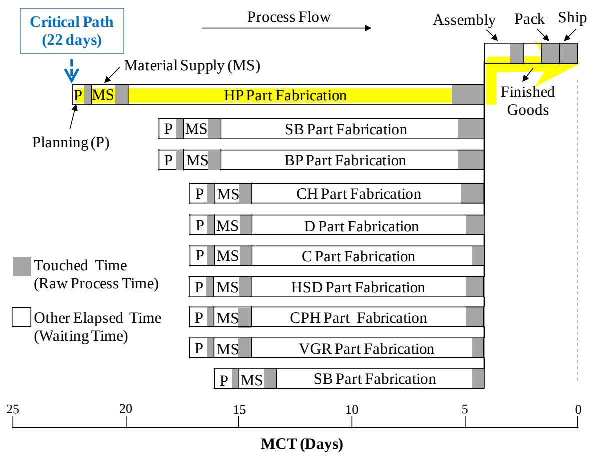

Figure 7: MCT / LT of Product BI

2.2 Changing Variability, Utilization and Raw Process Time (RPT)

Figure 8 shows the execution investigation through Operating Curves of item BI. The chart shows that LT increments with use and with inconstancy as a developing pace, exhibited by the expanding separation between the continuous bends. It demonstrates that use largerly affects LT than changeability, utilizing the current working point 'A' (dabbed bolts). The LT diminishes from 22.3 to 14 days (OTD target) is empowered by use decrease from 90% to 84% (by 7%) or CV decrease from 1.11 to 0.65 (by 41%). Be that as it may, decreasing the CV to either 0.65 or 0.32 to accomplish the OTD focus at the ideal use of 90% and 95% separately is a testing task because of the unavoidable useless changeability in this activity shops condition. Thus, we can just depend on QRM guideline to misuse the vital fluctuation through limit the board.

Figure 8 additionally delineates the effect of expanding inconstancy. In this figure we represent the end result for two frameworks that are indistinguishable with the exception of that one has a CV of 0.65 and different has a CV of 1.11. By the Queuing Delay Principle, the postpone will be almost multiple times higher for some random dimension of usage in the last framework than in the previous [7]. However, as we see from Figure 8, this has the impact of making delay in the framework with CV = 1.11 "explode" significantly more rapidly. Thus, on the off chance that we need to accomplish a similar dimension of postponement in these two

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frameworks, we should work the framework with CV = 1.11 at a much lower dimension of usage than we will almost certainly keep up in the framework with CV = 0.65.

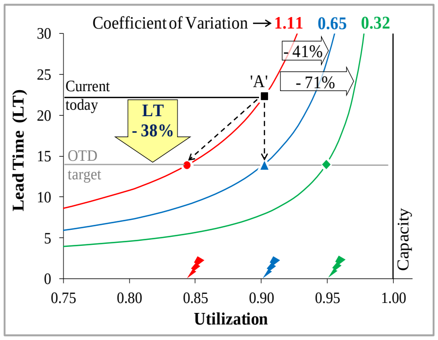

Figure 8: LT improvement analysis through reducing V and U

Diminishing crude procedure time (T) can be another LT decrease methodology as outlined in Figure 9. The chart shows'time decrease from 2 to 1.25 days (by 38%) and not 1.5 days (by 25%). Nonetheless, improving crude procedure time by 25% is increasingly functional temporarily, in which the organization can consider to control the limit use at 88% (with just minor drop of current use 90%) in the meantime so as to verify more business from clients with a responsibility of shorter LT. Be that as it may, this methodology require process overhauling that may not be commonsense in the high-blend and uniquely built condition where you are getting the new and diverse employment arranges more often than not.

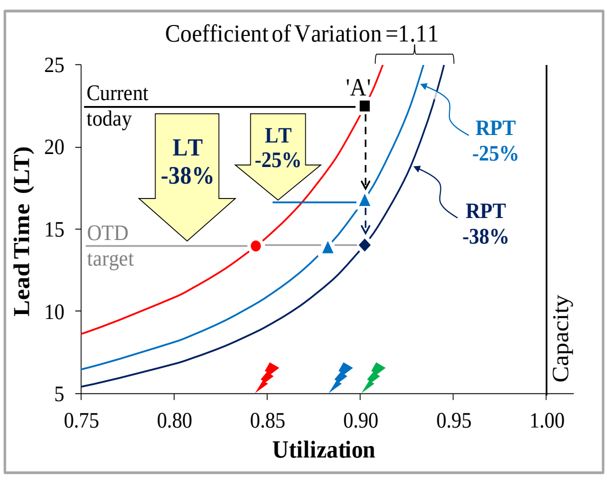

Figure 9: LT improvement analysis through reducing U and T

3. CONCLUSION

This paper has demonstrated the connection between limit use, changeability and procedure time inside work shop creation framework. The effect of lessening use, fluctuation and procedure time on this tradeoff has been examined. From the examination and dialog above, we can presume that use has higher impact on LT than changeability at high inconstancy condition important to high-blend, low-volume and exclusively designed makers.

The outcome is likewise in accordance with the case from Hopp and Spearman [8] that the two supporters of CT are use and changeability, of which use has the most sensational impact on CT than inconstancy; and the QRM standards from Suri [4] expressed that usage decrease is regularly the way to accomplishing high proficiency strategic frameworks in the activity shop condition.

In addition, since limit is expensive in the accuracy parts creation makers, high use is normally alluring for better benefit. Sadly it swings up to be the other route as the clients getting fretful of your poor conveyance execution and gradually diverting their business to your rival. As we gained from the lining hypothesis, the best way to have high use without long lining is to have a low fluctuation factor which isn't suitable in the activity shops.

Since QRM perceives that fluctuation can be imbued in such nature of an organization's the same old thing, it offers an alluring way to deal with these sorts of business for this very reason [12]. Henceforth, organizations should scrutinize their sound judgment presumptions and quit pushing for decreasing fluctuation through Lean. Rather they should work to deal with the limit use at the key dimension so as to improve execution and that the subsequent execution can be connected to decreasing LT and verifying more business in the long haul [13]. Despite the fact that the example information has given an empowering result utilizing QRM, it might constrain the generalizability of the discoveries to the more extensive activity shop populace. Future research is important to approve the discoveries from the present examination on a more extensive example of SMEs in different businesses that make custom items in little parcel sizes [14,15].

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REFERENCES

[1] M. J. Joing, "Applicability of Lean Manufacturing and Quick Response Manufacturing in a High-Mix Low-Volume Environment," Master Dissertation, Massachusetts Institute of Technology, 2004.

[2] W. C. How, "Hybrid POLCA in a job shop environment," Master Dissertation, Universiti Teknikal Malaysia Melaka, 2016.

[3] R. Pyrek, "Quick response manufacturing description," Tarnow Research Papers Collection, vol. 2, no. 16, pp. 109-115, 2010.

[4] R. Suri, *It's About Time: The Competitive Advantage of Quick Response Manufacturing*, Portland: Productivity Press, 2010.

[5] Shakeel PM, Baskar S, Dhulipala VS, Jaber MM., "Cloud based framework for diagnosis of diabetes mellitus using K-means clustering", Health information science and systems, 2018 Dec 1;6(1):16.https://doi.org/10.1007/s13755-018-0054-0

[6] L. Harding, "QRM – An Enabler on the Road to Agility? Quick Response Manufacturing – Part 1," Control, May: pg. 20-22, 2002.

[7] Panwala, Fenil C., R. Kumar, and P. Mohamed Shakeel. "An analysis of bacteria separation and filtration from blood sample using passive methods." Measurement (2019).https://doi.org/10.1016/j.measurement.2019.02.037

[8] W. J. Hopp and M. L. Spearman, *Factory Physics (2nd Ed)*, New York: Irwin McGraw Hill, 2001.

[9] Wu, K., "An Examination of Variability and Its Basic Properties for a Factory," IEEE Transactions On Semiconductor Manufacturing, vol. 18, no. 1, pp. 214–221 , February, 2005.

[10] R. Suri, MCT: Quick Reference Guide. Wisconsin: C&M Printing Inc., 2014.

[11] C. S. Bong, K. E. Chong and W. C. How, "Job shop material control based on the principles of quick response manufacturing," proceedings of the 5th International Conference on Design and Concurrent Engineering 2016, iDECON 2016, Malaysia, September 19-20, 2016.

[12] R. Suri, "QRM and POLCA: A winning combination for manufacturing enterprises in the 21st century," Technical Report, Center for Quick Response Manufacturing, May 2003

[13] Shakeel, P.M., Tolba, A., Al-Makhadmeh, Zafer Al-Makhadmeh, Mustafa Musa Jaber, "Automatic detection of lung cancer from biomedical data set using discrete AdaBoost optimized ensemble learning generalized neural networks", Neural Computing and Applications,2019,pp1-14.https://doi.org/10.1007/s00521-018-03972-2

[14] R. Suri, *Quick Response Manufacturing: A Company-wide Approach to reducing Lead Times*, New York: Productivity Press, 1998.

W.J. Hopp, *Supply Chain Science*, Chicago: Waveland Press, 2008.