Why Shortage Cost is more suitable for computing "Pull" Systems while Backorder Cost is preferred in "Push"

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Abstract
In introducing inventory control models, textbooks and journals rarely justify the use of Shortage and Backorder Costs, C_s and C_b, for their computation. This paper attempts to explain the rationale behind the use of these two costs by enacting a simple stock-out scenario. Since the inventory control literatures is largely classified into push or pull systems, one control system from each classification is selected for enactment: namely, the Traditional Kanban Control System (TKCS) – for pull; and the Base Stock (BS) – for push.

Keywords
Kanban, Base Stock (BS), Traditional Kanban Control System (TKCS), Backorder Cost, Shortage Cost

1. Introduction
A kanban system is a production mechanism which uses "production authorization cards" (kanbans) to control the work-in-process at each stage. A kanban is attached to every finished part. Once a customer demand arrives, the kanban that was attached to the finished part is removed and sent back to re-initiate the manufacturing production process while the finished part is shipped to the customer. In introducing inventory control models, textbooks and journals rarely justify the use of Shortage and Backorder Costs, C_s and C_b, for their computation. Two significant production control systems, the Traditional Kanban Control System (TKCS) and the Base Stock (BS) are chosen in this paper for explanation. They are chosen because they are the most symbolic systems to represent the *pull* and *push* inventory control theories respectively. In other words, a simple stock-out situation will be enacted on these two systems to demonstrate why most authors in the kanban literature prefer to use Shortage Cost, C_s, for Kanban Systems and Backorder Cost, C_b, for Base Stock. For simplicity, all systems described in this paper are of Single Stage (meaning single server, machine or Manufacturing Process (MP)) and Single Product.

Referring to Fig. 1, the Traditional Kanban System (TKCS) operates as follows: When a customer demand arrives at the system it joins Queue D_1 requesting the release of a finished product from B_1 to the customer. At that time there are two possibilities: If a part is available in B_1 (which is initially the case), it is released to the customer after detaching the kanban that was attached to it. This kanban is transferred upstream to Queue K_1, carrying with it a demand signal for the production of a new stage 2 finished part. If no part is available in B_1, the demand is backordered and waits in Queue D_1 until a new part is completed and arrives in B_1. The newly finished part will be released to the customer instantly and the detached kanban will transfer to Queue K_1 instantly too. B_0 is the raw material inventory buffer and it's assumed to carry infinite stock.

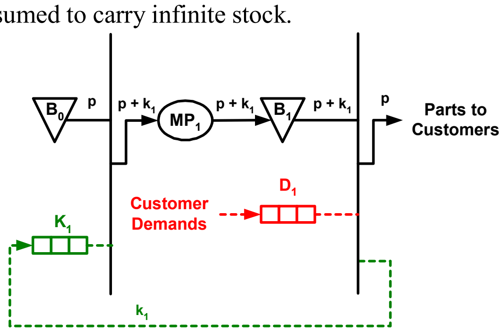

Figure 1 A Single Stage, Single Product Traditional Kanban Control System (SS/SP/TKCS) (Sugimori,

Kusunoki, Cho, & Uchikawa, 1977)

Fig. 2 shows the Base Stock (BS) System. It works the same way as Fig. 1, except it does not contain kanbans and has instantaneous transmission of demands. Also, s_1 represents its *base stock* level carried in the output buffer B_1 – hence the name BS.

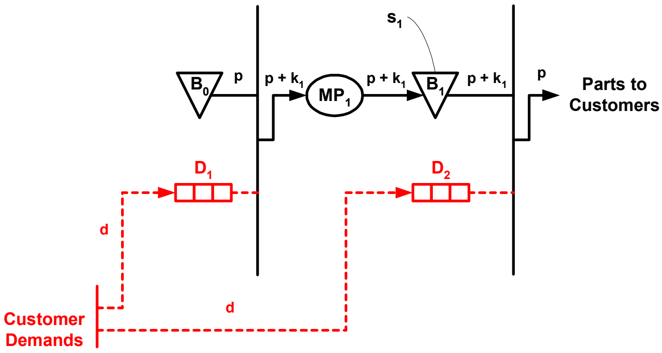

Figure 2 A Single Stage, Single Product Base Stock System (SS/SP/BS) (Clark & Scarf, 1960)

2. Definition of Terms

In most of the kanban and base stock literature, the terms "Shortage" and "Backorder" are loosely defined (Askin, Mitwasi, & Goldberg, 1993; Hopp & Spearman, 2008; Nori & Sarker, 1998; Wang & Hsu-Pin, 1991; Zipkin, 2000). Sometimes, they can both refer to the same thing e.g. both can mean lost sales per unit time; while at other times, they may refer to the duration of a stock out situation. In this paper, Shortage Cost, C_s, is defined as the duration of a stock out situation. In other words, ***C_s is "per unit time"*** and the state space is focused on the output buffer. So long as the output buffer is empty, C_s is incurred per unit time. Backorder Cost, C_b, is defined as the number of lost sales per unit time. In other words, ***C_b is "per unit per unit time"*** and the state space is focused on the demand queue. An increasing number of unsatisfied customers held at the demand queue signify an increase in the average number of backorders – and hence incurring higher C_b.

3. Key Difference between TKCS and BS

To understand why C_s fits TKCS and C_b fits BS better, we must first understand the key difference between TKCS and BS. According to Hopp and Spearman (2008), TKCS and BS are very much alike, with the number of kanbans in TKCS acting as the base stock level for BS and kanban acting as a "demand signal" for previous stages in a BS.

But "*a key difference is that BS does not limit the amount of work that can be in process while the kanban system does (i.e. the backlog in a BS can exceed the production card count in a kanban system)."*(Hopp & Spearman, 2008) This is better explained using the figures below.

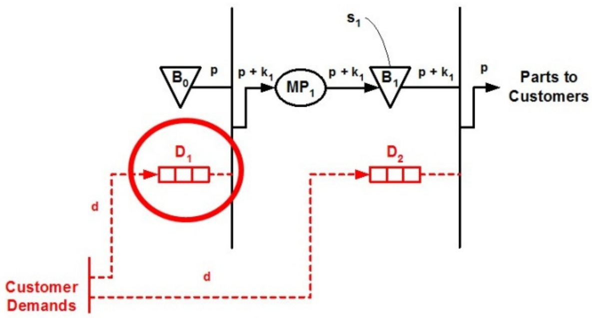

Figure 3: SS/SP/BS

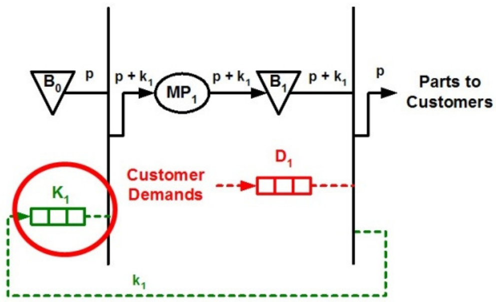

Figure 4: SS/SP/TKCS

In Figure 3, BS does not limit the amount of WIP that enters into the MP. Any amount of demands coming into queue D_1 is immediately sent into the MP for processing. However, for Figure 4, the amount of WIP allowed into MP is constrained by K, the number of kanbans.

5. How do TKCS and BS respond to a stock out situation?

We cite an example to see how TKCS and BS react to a stock out situation. Then we are able to understand why C_s fits TKCS and C_b fits BS. These are some basic assumptions:

- The number of Base Stock, S, for BS and the number of kanbans, K, for TKCS both equal 1. That is, there is only 1 base stock for BS and only 1 kanban for TKCS. It is necessary for both of them to be equal so that we can compare them fairly. In fact, since K = 1, this attached kanban in output buffer B_1 is similar to saying S = 1 for BS.
- MP has 3 parallel and identical servers. This means that at any one time, MP can process 3 parts.
- At this instance, 3 demands have arrived.

At t = 0,

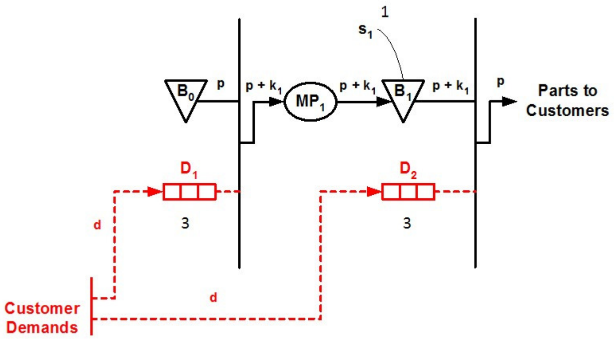

Figure 5: SS/SP/BS at t = 0

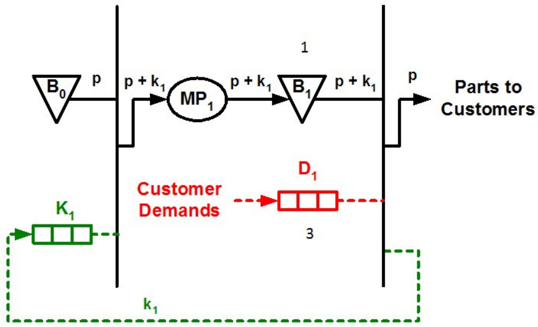

Figure 6: SS/SP/TKCS at t = 0

At t = 1,

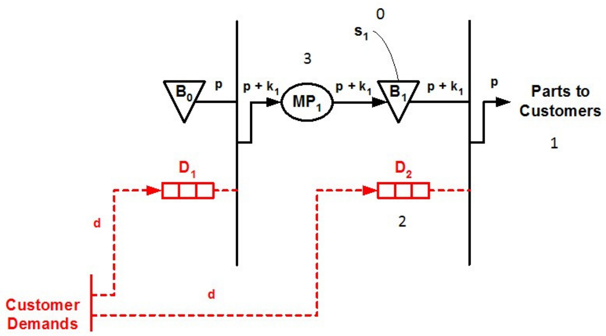

Figure 7: SS/SP/BS at t = 1

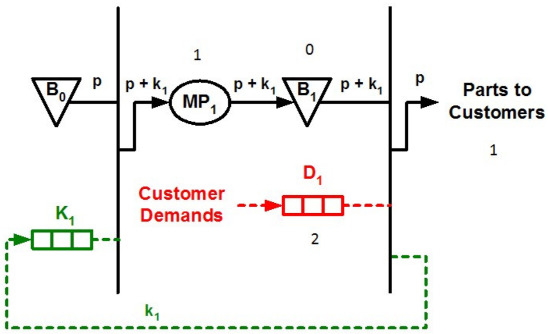

Figure 8: SS/SP/TKCS at t = 1

At t = 2,

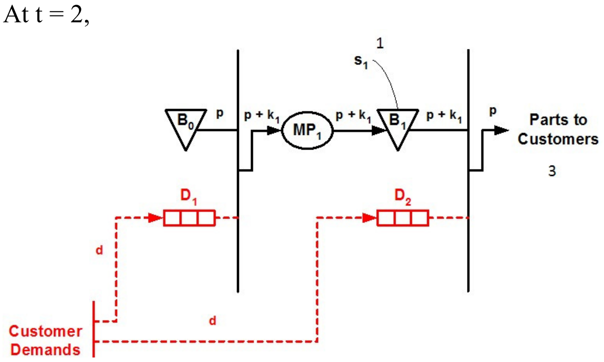

Figure 9: SS/SP/BS at t = 2

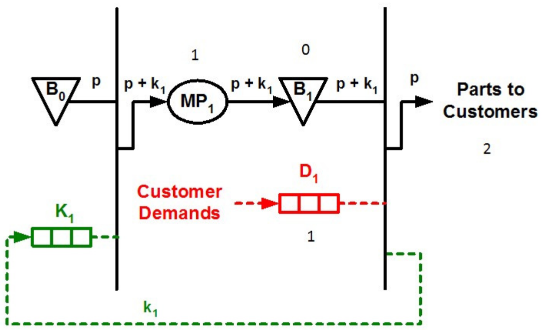

Figure 10: SS/SP/TKCS at t = 2

At t = 3,

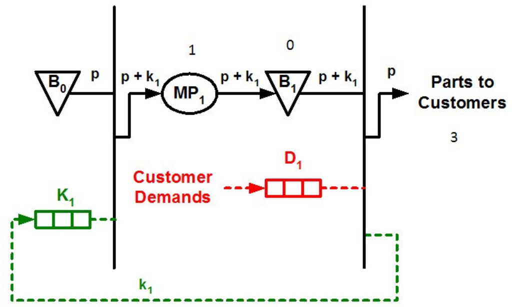

Figure 11: SS/SP/TKCS at t = 3

At t = 4,

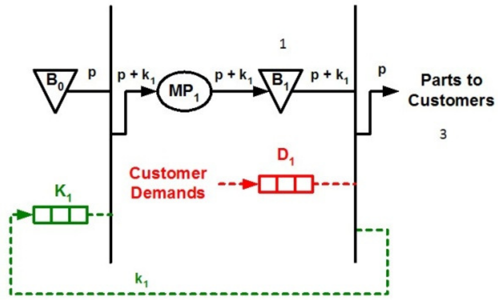

Figure 12: SS/SP/TKCS at t = 4

With regards to the figures above, TKCS has taken 4 time periods to satisfy all 3 demands. But BS only used 2 time periods. This shows that TKCS is in shortage mode for a longer time than BS. Hence a more suited performance indicator for TKCS should be C_s. As for BS, it should concern itself more with number of backorders since it tries to satisfy all demands at one go. Hence C_b is more suited for BS.

6. Conclusion

In introducing inventory control models, textbooks and journals rarely justify the use of Shortage and Backorder Costs, C_s and C_b, for their computation. In this short paper, a simple scenario is enacted on the Single Stage, Single Product Traditional Kanban Control System (SS/SP/TKCS) and the Single Stage, Single Product Base Stock (SS/SP/BS) to demonstrate why most authors in the kanban literature prefer to use Shortage Cost, C_s, for Kanban Systems and Backorder Cost, C_b, for Base Stock.

Although at the end of the day, the choice between C_s and C_b for modeling these systems is at the discretion of the researcher (depending on the requirements), the attributes of these systems attract the respective costs for modeling. Overall, it is due to TKCS limiting Work-In-Process (WIP) by use of kanbans that increases customers' waiting / shortage time. Hence shortage cost impacts TKCS greater. As for BS, it does not limit WIP – hence if its MP has the capacity to meet the backorders at one go, then shortage time is not much of a concern for BS. Instead, backorder cost is more impactful for BS.

Finally, it is the hope that the simple stock-out scenario enacted in this paper can convincingly illustrate why Shortage and Backorder Costs, C_s and C_b, are used for computing *pull* and *push* systems in most textbooks and journals, generally speaking.

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Biography

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