Development of Computer Simulation Instruction (CSI) Software for Kanban and Pull System Training Class

Thuthavorn T.
Graduate School in Industrial Management, Thai-Nichi Institute of Technology, Bangkok, Thailand

Hemsathapat K.
Graduate School in Industrial Management, Thai-Nichi Institute of Technology, Bangkok, Thailand

Pakkaraprommin V.
Department of Business Administration, Thai-Nichi Institute of Technology, Bangkok, Thailand

Abstract
In Toyota Production System training class, content of the class related to Kanban and Pull system is rather complex for instructor to explain to the class. Generally, live simulation is effectively employed during complex training part. However, training equipments for live simulation are expensive. Maintenance cost and transportation of these equipments are high and inconvenience. Moreover, simulation patterns are limited due to equipment attributes. In this study, Computer Simulation Instruction (CSI) software for Kanban and Pull system was developed under the principle of discrete-event software to unravel the aforementioned problems. The developed CSI software will be utilized in TPS class.

***Keywords**: Toyota production System (TPS), Kanban, Pull system, Computer simulation instruction (CSI), Discrete-event software, Training class*

1 Introduction

Toyota Production System (TPS) is a practice and philosophy developed by Toyota Corporation after the World War II for reducing wastes in manufacturing system. The most important objective of TPS is to increase production efficiency by eliminating wastes, solving problems, and continuously improving. Wastes in anything add cost, but not value, to a product.

For more than 20 years, TPS has been widely accepted as a proven method to improve productivity and reduce cycle time. Unfortunately, it is not quite popular among small and medium-sized companies. The main problem is that small and medium-sized companies lack adequate trainings and proper equipments to learn and educate their employees about TPS concepts and its applications. Consequently, many TPS/Lean training courses are presently offered [1]. However, most of TPS/Lean training courses are using live simulation technique.

2 Problem Statements

Toyota Production System course (IMA-710) offering at Thai-Nichi Institute of Technology (TNI) was initially developed by jointed cooperation between TNI and Toyota Motor Asia Pacific (TMAP) by employing live simulation technique as shown in Figure 1. Some of the equipments were donated from the TPS training center at TMAP. In setting a live simulation, small plastic components (Lego or something in similar) representing products/assembly parts and adjustable plastic boxes representing waiting post, Heijunka post are utilized. This kind of live simulation technique is an effective teaching tool that makes complex concepts easy to grasp.

When considering wastes under TPS concept, live simulation technique in IMA-710 has two forms of wastes. The first waste is excessive inventory because the cost of equipments/components is excessive to cover all live simulation scenarios. The second waste is over processing because the time spent to setup the equipments for each live simulation scenario is considered a waste.

In addition, the limitation of simulation scenarios due to the equipment attributes is a shortcoming of live simulation technique.

To unravel this problem, Kanban and Pull System Computer Simulation Instruction (KPS-CSI) was developed to support instructor as a computer software simulation tool, and to substitute live simulation in the part of Kanban and Pull system of IMA-710 class. The investigation is being conducted to answer the following problem statements regarding KPS-CSI in comparison with live simulation:

- Is the training cost of KPS-CSI less than the training cost of live simulation?
- Is the training time of KPS-CSI quicker than the training time of live simulation?
- Are simulation scenarios of Kanban and Pull system in KPS-CSI greater than those offered in live simulation?
- Does KPS-CSI achieve comparable educational objectives as live simulation?

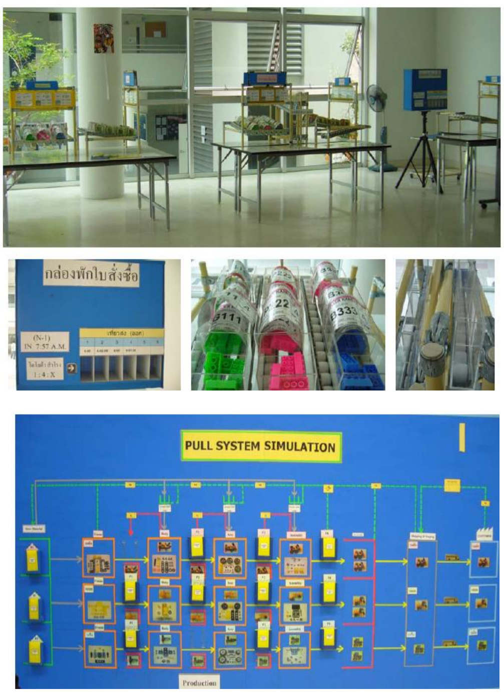

Figure 1: Toyota Production System Live Simulation Equipments at TNI

3 Literature Review

To avoid repeating known research efforts, a literature review was conducted to cover the following topics; Kanban and Pull System simulation in IMA-710 class, Computer-Aided Simulation (CAI) training, TPS/Lean manufacturing training with live simulation, and TPS/Lean manufacturing training with CAI

3.1 *Toyota Production System Course (IMA-710)*

IMA-710 course offering at Thai-Nichi Institute of Technology was designed and classified into four lessons which are explained in details in [2]. The first lesson is worksite control, a technique employed in many places and contexts whereby control of an activity or process of shop floor area is made easier or more effective by deliberate use of visual signals. The second lesson is continuous flow, a methodology for producing and moving item at a time (or a small and consistent batch of items) through a series of processing step as continuously as possible, with each step making just what is requested by the next step. The third lesson is standardized work, establishment of precise procedures for each operator’s work in a production process based on Takt time. The fourth lesson is Pull system, a methodology of production control in which downstream activities signal their needs to upstream activities. Pull system strives to eliminate overproduction. In pull system, a downstream operation, whether within the same facility or in a separate facility, provides information to the upstream operation, often via a Kanban card about what part or material is needed, the number of quantity needed, and when and where it is needed. Nothing is produced by the upstream supplier process until the downstream customer process signal a need.

3.2 *Kanban and Pull System Simulation*

Kanban and Pull system simulation in IMA-710 is a practice session to improve student understanding to Kanban and Pull System concept and its tools by live simulation. Three basic simulation scenarios of Kanban and Pull system taught in IMA-710 are Kanban by Kanban, lot making post, and pattern post.

3.3 *TPS Tools*

3.3.1 Kanban

Kanban is a fundamental tool for developing a Just-In-Time production system, which mean produce what is needed, when it is needed and in what quantity is needed. In Kanban and Pull system, there are two types of Kanban [3]. The first is Production Instruction Kanban (PI Kanban) that is used to tell upstream process the type and quantity of products to make for a downstream process. The second is Part withdrawal Kanban (PW Kanban) that is used to withdraw part from preceding process.

3.3.2 Waiting Post

Waiting post as shown in Figure 2 is a tool that is used to represent and control in-and-out timing of customer order data making shipping operation to be Just-In-Time with the least stagnation [3].

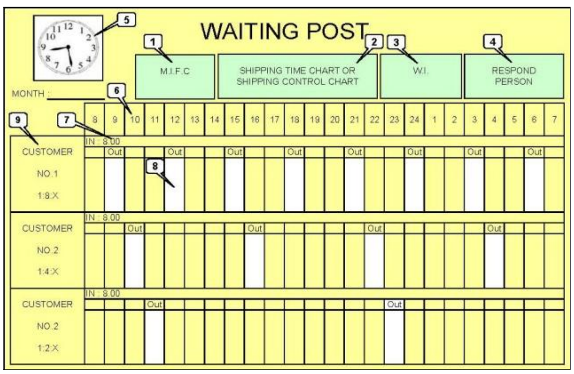

Figure 2: Example of a Waiting Post from KPS-CSI

3.3.3 Heijunka Post

Heijunka post as shown in Figure 3 is a tool that is used to level volume and part variety from customer before sending information to production line. Heijunka is the overall leveling in the production schedule of variety and volume of items produced in given time period. It is a prerequisite for Just-In-Time production [3].

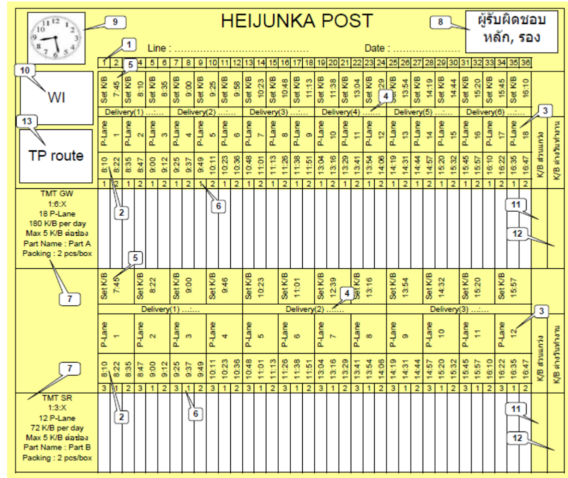

Figure 3: Example of a Heijunka Post from KPS-CSI

3.3.4 Lot Making Post (Fixed Quantity Post)

Lot making post as shown in Figure 4 is a tool that is used in the production that fixes the certain quantity for each time period (fixed quantity) because in some cases, production line needs a long period of time to setup a new model production. If Kanban by Kanban production is chosen instead, a big loss of time can be occurred. Thus, a lot size production is a solution to this problem [3].

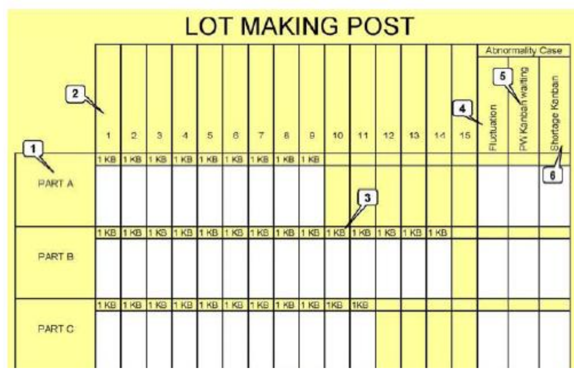

Figure 4: Example of a Lot Making Post from KPS-CSI

3.3.5 Pattern Post (Fixed Period Post)

Pattern post is a tool that is used in the production system that uses 'time' to control the production. The necessity of fixed period production is up to what kind of setup is taking long time. Normally, fixed period production is more suitable for a production that required very long setup time. For example, injection process that needs a long setup time to warm up mold. Painting process also takes long setup time [3]. The fixed period production usually produces just one lot per day and does not require producing everyday. In fixed period production as shown in Figure 5, PI Kanban is accumulated at the pattern post. Then, the progressive post is signaled to set production schedule.

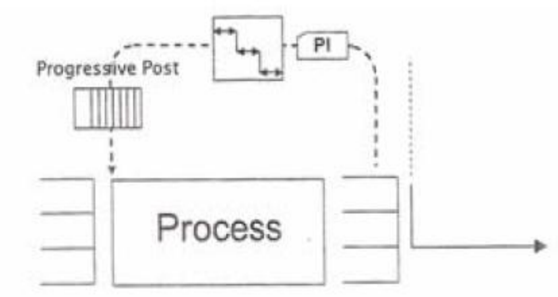

Figure 5: Fixed Period Production

3.4 *TPS/Lean Training with Live Simulation*

According to [1], as of October 2003, there were 17 different TPS/Lean training courses offering such as TimeWise Simulation of Lean 101 Training Program by MEP-MSI, Lean Enterprise Value Simulation by Lean Aerospace Initiative, and Paper Airplane Game by Northrop Grumman. All of these training courses were employing live simulation. From October 2003 until 2010, there were tremendous increase in TPS/Lean training courses with live simulation such as a hands-on Kanban Simulation Kit for Lean Manufacturing [4] and many other training courses represented on American Society for Engineering Education Conference [5].

All of aforementioned studies confirm that the simulation technique for training assistance was proven a success. In addition, the link between the simulation and CDIO (Comprehend-Design-Implement-Operate) concepts was introduced [6]. The link is reinforced by the fact that most process improvement methods themselves suggest a set of actions that sound very much like CDIO.

3.5 *TPS/Lean Training with Computer Simulation Instruction (CSI)*

According to [7], Computer Simulation Instruction (CSI) for lean manufacturing training was developed by using the discrete-event software called ProModel with user friendly interface created from Microsoft Visual Basic and ActiveX. With this development, this CSI is easy to use for instructor in training. At the same time, the powerful simulation process remains unchanged. Moreover, additional lean concepts that are not covered in live simulation can be taught. In addition, the training time for CSI is less than live simulation does. Consequently, this CSI can achieve comparable education objective as live simulation does.

ProModel University developed Lean training course incorporated with Microsoft Visio [8]. This CSI have more complete functions and more effective than other CSI. It uses Microsoft Visio as a user interface in order to draw a complex process diagram and to submit a diagram to ProModel to simulate and get results in real time.

3.6 *Computer-Assisted Instruction (CAI)*

Computer-Assisted Instruction or Computer-Aided Instruction (CAI) is an interactive instructional technique whereby a computer is used to present the instructional material and monitor the learning that takes place. CAI uses a combination of text, graphics, sound and video in enhancing the learning process. The computer has many purposes in the classroom, and it can be utilized to help a student in all areas of the curriculum. CAI refers to the use of the computer as a tool to facilitate and improve instruction. CAI programs use tutorials, practice, simulation, and problem solving approaches to present topics, and test the student's understanding [9].

Several studies [10, 11, 12] indicate that CAI is an effective learning tool. Two suggestions for a successful CAI development are consistency of the content of CAI with the textbook, and instructor-lead for CAI deployment.

In summary, CSI is proven to be an effective tool for development of TPS/Lean training course. Discrete-event simulation software, for example, ProModel is an effective development tools for CSI. Unfortunately, two major tools in KPS-CSI, waiting post and Heijunka post, cannot be developed from discrete-event simulation software because shape and dimension of waiting post and Heijunka post cannot be dynamically altered when changes in simulation scenarios [13].

4 Research Methodology

4.1 *Development of KPS-CSI*

The study of IMA-710 course description with specific to Pull model was carried out to assure that the content of IMA-710 is consistent with simulation software specification. The structure of KPS-CSI is shown in Figure 6.

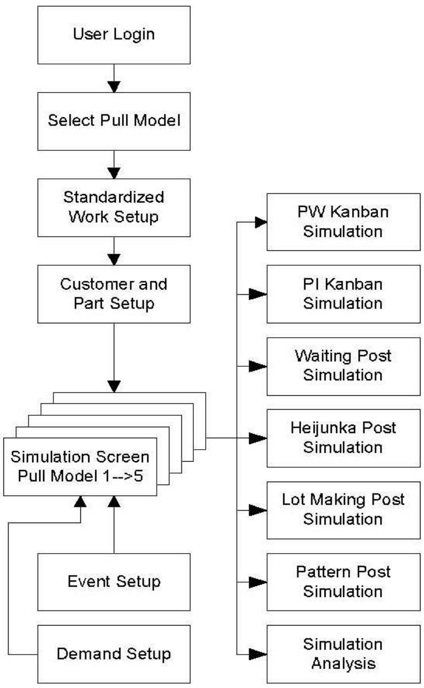

Figure 6: Structure of KPS-CSI

Five simulation scenarios of KPS-CSI are being developed to cover IMA-710 course content. Examples of eKanban Direct Heijunka and PW Kanban Heijunka with fixed quantity are shown in Figure 7 and 8, respectively. The five scenarios are the following.

- eKanban Direct Heijunka,
  Kanban by Kanban
- PW Kanban Heijunka, Kanban by Kanban
- PW Kanban Heijunka, Fixed Quantity
- PW Kanban Heijunka, Fixed Period
- eKanban Direct Heijunka,
  With Abnormality Rules

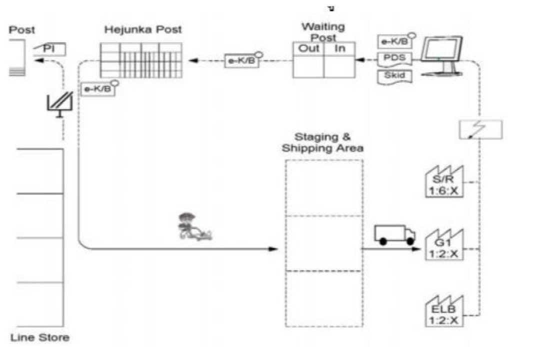

Figure 7: Example of eKanban Direct Heijunka from KPS-CSI

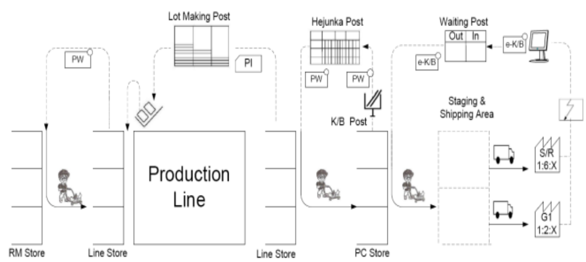

Figure 8: Example of PW Kanban Heijunka, Fixed Quantity from KPS-CSI

4.2 *Development Tool*

Sybase PowerBuilder.Net Version 12 is selected to be the computer language to develop KPS-CSI software.

4.3 *Research Population*

To verify the effectiveness of the KPS-CSI, research subjects must be chosen in this study. Research subjects are the students of IMA-710 taken at Thai-Nichi Institute of Technology. The research subjects must previously pass IMA-710, and are willing to be included in the research population.

4.4 *Try Out Method*

The One Group Pretest-Posttest design is selected for experiment.

4.5 *Survey Forms for KPS-CSI Evaluation*

To answer the problem statements regarding training cost, setup time, and additional TPS Pull simulation scenarios, comparison between KPS-CSI and live simulation method can be easily conducted. However, to answer the problem statement regarding KPS-CSI can achieve comparable education objectives as live simulation does, standard examination is used and developed by the instructor. In addition, course satisfaction survey is used to evaluate student satisfaction of KPS-CSI.

4.6 *Implementation Procedures*

The implementation procedures are designed as the following steps:

- The standard examination developed will be used for testing learning achievement. It will be tried out by letting the sample group take a pretest.
- After pretest, the sample group will be taught with KPS-CSI.
- After experiment, the same test will be used for testing learning achievement by letting the sample group takes the posttest.
- Then, the sample group will be asked to answer satisfaction survey form comparing between live simulation and KPS-CSI.
- Lastly, the instructor will be asked to compare cost, setup time, and the number of Pull model simulation scenarios between live simulation and KPS-CSI.

4.7 *Data Analysis*

4.7.1 Efficiency of KPS-CSI

Meguigans ratio as shown in Equation (1) is selected to evaluate the efficiency of the KPS-CSI.

$$\text{Meguigans Ratio} = \frac{M2 - M1}{P\text{-}M1} + \frac{M2 - M1}{P} \quad (1)$$

Some of the equipments were donated from

M1 = average score of pretest
M2 = average score of posttest
P = maximum score of the test

Meguigans ratio is ranged between 0 and 2. If the ratio is greater than 1, the KPS-CSI will be considered efficiency [14].

4.7.2 Effectiveness of the KPS-CSI Lesson

T-test is selected to evaluate the effectiveness of the KPS-CSI as shown in Equation (2).

$$t = \frac{\sum D}{\sqrt{\frac{n\sum D^2 - \left(\sum D\right)^2}{n-1}}} \quad (2)$$

$\sum D$ = Total sum of the difference between average scores of pretest and posttest

$\sum D^2$ = Total sum of the difference between average scores of pretest and posttest, squared

D = The difference between scores of pretest and posttest of each sample

n = Total number of students

If the T-test is greater than 0.5, it is proven that the pretest and posttest scores are different.

4.7.3 Comparison of Student Satisfaction

Two sample T-test is selected to evaluate student satisfaction between live simulation and KPS-CSI as shown in Equation (3).

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\left[\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}\right]\left[\frac{1}{n_1} + \frac{1}{n_2}\right]}} \quad (3)$$

$\overline{X}1$ = mean scores of student satisfaction evaluation with KPS-CSI

$\overline{X}2$ = mean scores of student satisfaction evaluation with live simulation

S_1^2 = variance of scores of student satisfaction evaluation with KPS-CSI

S_2^2 = variance of scores of student satisfaction evaluation with live simulation

n_1 = number of student taught with KPS-CSI

n_2 = number of student taught with live simulation

df = degree of freedom, n_1+n_2-2

The T-test for student satisfaction taught with KPS-CSI must be greater than 0.5 to be proven satisfactory over live simulation.

5 Results

Currently, KPS-CSI software is under development. All the training scenarios and the results from the student evaluations for efficiency, effectiveness, and satisfactory will be represented at the GCMM 2010 proceedings. Upon completion, the KPS-CSI software will be utilized in IMA-710 class in the academic year of 2011.

Acknowledgments

The authors would like to extend sincere gratitude to King Mongkut's University of Technology North Bangkok and Thai-Nichi Institute of Technology for supporting this paper.

References

[1] Alok K. Verma, 2003. Simulation Tools and Training Programs in Lean Manufacturing – Current Status (Final Report), Old Dominion University, Norfolk.

[2] TPS Promotion Section, Purchasing Engineering (TMAP-EM), 2008. Toyota Production System Book 1 & 2, Toyota Motor Asia Pacific Co., Ltd, Bangkok, Thailand.

[3] TPS Promotion Section, Purchasing Engineering (TMAP-EM), 2008. TPS Practical Manual Book3, Toyota Motor Asia Pacific Co., Ltd, Bangkok, Thailand.

[4] Shaojun Wang and Doug Kook, 2008. A Hands-on Kanban Simulation Kit for Lean Manufacturing, Proceedings of the 2008 IAJC-IJME International Conference, Southeast Missouri State University, USA.

[5] Hung-da Wan, F. Frank Chen and Can Sayin, 2008. Simulation and Training for Lean Implement Using Web-based Technology, Services Operation and Informatics, Vol. 3, No.1.

[6] Hugh L. McManus, 2007. Teaching Lean Thinking Principles through Hands-on Simulation, Proceedings of the 3rd International CDIO Conference, MIT, and Cambridge, Massachusetts, USA.

[7] Luoding Paul Wang, 2005. Computer-Simulation Assisted Lean Manufacturing Training, School of Technology Brigham Yong University, Salt Lake City, UT.

[8] ProModel, 2010. ProModel University, Last Access from: http://www.promodel.com/services/training/university.asp [July 10, 2010].

[9] Apinan Banditnukul, 2006. The Development and Efficiency Validation of a Computer Assisted Instruction Program in Teaching Concrete Technology on "Fresh Concrete", King Mongkut's Institue of Technology North Bangkok, Bangkok, Thailand.

[10] Amanda M. Klein, 2005. The Effects of Computer Assisted Instruction on College Algebra Students at Texas Tech University, Graduate Faculty of Texas Tech University, Texas, USA.

[11] Carmelita Y. Ragasa, 2008. A Comparison of Computer-Assisted Instruction and the Traditional Method of Teaching Basic Statistics, Journal of Statistics Education, Vol.16, No.1.

[12] Michael S. Jenk, A view of the Research on the effect of CAI Electronic Journal for the Integration of Technology in Education, Vol.1, No.2.

[13] Charles Harrell; Biman K. Ghosh and Royce O. Bowden, Simulation Using ProModel 2nd Edition, McGraw-Hill, New York.

[14] Mana Prateepornsak, 2006. The Development of Multimedia-Based Instruction for the Deaf in "The Life of The Lord Buddha", King Mongkut's Institute of Technology North Bangkok, Bangkok, Thailand.