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***Seru* Production (セル生産) and its context, mechanism, performance, and design← (プロジェクト名記載)**

オムロン基金研究プロジェクト2019年度最終報告書

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1) 活動実績

This is a three-year (2018.April - 2020.March) research project that focuses on “*Seru* Production and its context, mechanism, performance, and design”.

The research objective has three parts: (1). List out of a large number of research topics related to *seru* production system, emphasize four research aspects for new system adoption – applicability, justification, system design, and implementation. (2). Compare with other production systems: Make use of several paradigmatic and theoretical lenses to aid understanding of these factors, including lean and agile manufacturing paradigms, cellular manufacturing concepts, and the Theory of Swift, Even Flow (TSEF, Schmenner and Swink, 1998). Our analysis yields a set of testable propositions that describe how and why manufacturing under *seru* can be profitable in a high-cost environment, and it identifies structural factors that may be transferable to other industries and contexts. (3). *Seru* design: How to design the configuration of a *seru* system and how to allocate customer orders to specific *serus* are difficult decision issues. In *genba*, these tasks are usually relied on the experiences of front-line managers. This research develops optimal methodologies to design a *seru* production system. This will benefit Japanese manufacturing factories. In this year, multi-skilled worker assignment problem in *seru* production systems is considered.

In the first year, a big workshop of *seru* production system and Industry 4.0 was delivered in December 3rd-8th, 2017. Attendances included main researchers in this area (e.g., Kathryn E Stecke, Morgan Swink, Suzanne de Trivelle, Ikou Kaku, and others.).

In the second year, the research group of this project has attended an international conference to present *seru* production systems. Several speakers from Japan, United States, China are invited to Doshisha Business School to present their ideas on production systems.

In the third year, a big workshop about *seru* and future research has been planned to be held in Kyoto. Unfortunately, due to the crisis of corona virus (COVID-19), all events have been canceled.

2) プロジェクトから得られた成果

The research results of this project (2017.April - 2020.March) have been delivered in more than 15 publications. Key results are in two papers. One is an Award paper and the other one is Highly Cited Paper (i.e., Top 1%) surveyed by Essential Science Indicators (ESI). The contents are as follows.

The award paper is a comparison between different production systems, which was presented in “Lessons from *seru* production on manufacturing competitively in a high cost environment” of *Journal of Operations Management*. High capital and labor costs, coupled with high rates of technological and competitive change, present challenges for manufacturers in developed countries, often spurring them to offshore production to low cost sources. However, the electronics industry provides an exception to this trend, where dynamic, high cost conditions have given rise to a new production system - *seru* - a cellular assembly approach. *Seru* evolved as an alternative to lean systems approaches, manifesting important differentiated system design choices that appear to offer promise for manufacturing in dynamic, high-cost markets. This paper reports the results of in-depth, longitudinal case studies of two electronics giants who have implemented *seru*. The case studies describe *seru*'s fundamental extensions to, and departures from, lean production, agile production, and group technology-based cellular manufacturing. We explain how Sony and Canon have applied *seru* to improve productivity, quality, and flexibility in ways that have enabled them to remain competitive. In addition, our findings elaborate the theory of swift, even flow, with implications for future research of trade-offs related to production efficiency, responsiveness, and competitiveness in high-cost, technologically dynamic markets.

The ESI highly cited paper is about Industry 4.0. In the Industry 2.0 through Industry 4.0 environment, the production systems evolution is reviewed. Our research discusses production systems with a focus on the relationships between product supply and customer demand in the context of Industry 2.0–4.0. One driver of production evolution is changes in customer demand over time, which is categorised into several dimensions. Major production systems - flow line, Toyota production system (TPS), job shop, cell, flexible manufacturing system and *seru* - have been developed and applied to supplies to match different demand dimensions over time. For each production system, two questions are addressed: *what* and *how*. Comparisons between *seru* with TPS and cell are given. The possibilities of a future smart factory equipped with internet of things are discussed. The demand dimensions of Industry 4.0, the product architecture change in the automobile industry and the impact of 3D printing are elaborated. Potential applications of lean and *seru* principles for Industry 4.0 are presented. This paper has been cited 143 time even only published two years.

3) 成果物 (出版物、研究発表、講演など)

One international award

➤ Best Paper Award Honorable Mention (Jack Meredith), 2018, *Journal of Operations Management*, which is one of top journals listed in FT50, UTD24, ABS4*.

The award ceremony was held at the annual meeting of the Academy of Management, the world's most prestigious conference in the field of business administration, in Chicago from Friday, August 10, 2018 to Tuesday, August 13, where the award was presented.

This winning paper was reported as one of the most cited papers. The citation is 61 times (Apr 29, 2020).

Invited Keynote Speech

Was be invited to the 2019 *International Conference of Production Research*, the world's most prestigious conference in the field of production management, as the Keynote Speaker at its annual meeting (In Chicago, USA). It is held every three years.

Many international Journal papers

1. **Y Yin**, KE Stecke, M Swink, I Kaku, Lessons from *seru* production on manufacturing competitively in a high cost environment. *Journal of Operations Management*, Vol.49-51, pp.67-76, 2017.

2. L.Luo, Z.Zhang and Y.Yin "Modelling and numerical analysis of seru loading problem under uncertainty", *European Journal of Industrial Engineering*, Vol.11, No.2, pp.185-204, 2017.

3. X.L.Zhang, C.G.Liu, W.J.Li, S.Evans and Y.Yin "Effects of key enabling technologies for seru production on sustainable performance", *OMEGA*, Vol.66, pp.290-307, 2017.

4. 吴旭辉, 李冬妮, 王帅, 于洋, 殷勇 "一种基于协同进化的流水线向 *seru* 系统转化方法" *自动化学报*, 2017.

5. D Li, R Guo, R Zhan, **Y Yin**, An innovative artificial bee colony algorithm and its application to a practical intercell scheduling problem. *Engineering Optimization*, Vol.50, pp.933-948, 2018.

6. Kaku, I., Yin, Y., & Süer, G. Several remarkable issues in Japanese *seru* production systems. in *Cellular Manufacturing Systems: Recent Developments, Analysis and Case Studies*. pp.303-326, © 2018 by Nova Science Publishers, Inc..

7. **Y Yin**, KE Stecke, D Li, The evolution of production systems from Industry 2.0 through Industry 4.0. *International Journal of Production Research*, 56 (1-2), 848-861, 2018.

Highly Cited Paper (i.e., Top 1%) surveyed by Essential Science Indicators (ESI). The citation is 147 times (Apr 29, 2020).

8. J Lian, CG Liu, WJ Li, **Y Yin**, A multi-skilled worker assignment problem in *seru* production systems considering the worker heterogeneity *Computers & Industrial Engineering*, 118, 366-382, 2018.

9. Wang.Y, Zhang.Z, and **Yin.Y**, Workload-based order acceptance in *seru* production system *International Journal of Manufacturing Research*, accepted, 2019.

10. Zhang.Z, Shao.L, and **Yin.Y**, PSO-based algorithm for solving lots splitting in unbalanced *seru* production system *International Journal of Industrial and Systems Engineering*, accepted, 2019.

11. L, Luo., Zhang, Z., & Yin, Y. Simulated annealing and genetic algorithm-based method for a bi-Level *seru* loading problem with worker assignment in *seru* production systems. *Journal of Industrial and Management Optimization*, 13(5), 0, 2019.

12. Y, Wang., Zhang, Z., & Yin, Y. An order scheduling problem in *seru* production system considering worker assignment. *International Journal of Industrial and Systems Engineering*, forthcoming, 2019.

13. X, Han., Zhang, Z., & Yin, Y. Reliability-oriented multi-resource allocation for *seru* production system with stochastic capacity. *International Journal of Manufacturing Research*, forthcoming, 2019.

14. Süer, G., Ulutas, B., Kaku, I., & Yin, Y. (2019). Considering Product Life Cycle Stages and Worker Skill Level in *Seru* Production Systems. *Procedia Manufacturing*, 39, 1097-1103.

15. Yu-Zhou, J., Dong-Ni, L., Hong-Bo, J., & Yin, Y. (2020). An online algorithm for parallel scheduling of *serus* with resource conflicts. *Acta Automatica Sinica*, 46, 1-16.

And others.

4) 申請書に記述された内容と成果の比較 (達成度についての自己評価, これまでの成果を踏まえた今後の研究計画)

In the application form, the goal is to create our research group (Doshisha Business School is the core center of this research group) becoming leader in the area of *servo* production (i.e., academic performance evaluated by academic publications in quantities and qualities).

During 2017-2020, the final targets are generating results of at least 15 high-quality publications.

Results: during the research years (2017-2020), we have published around 20 papers.

We only listed 15 publications above in the last page.

In the third year, due to the crisis of corona virus (COVID-19), some writing plans have not been completed. Especially the Japanese article, which will summarize the research in the past three years. But will continue this project and publish Japanese articles in the near future.

5) 予算案と予算執行実績についての説明（予算案に沿って研究を進め、予算を執行したかどうかを示す。予算案との乖離があった場合には、その理由を説明する）

There was a discrepancy between the budget and the implementation in the following two areas.

1. Travel expenses for research:

From 2017 to 2018, I was in charge of the department head, so was busy with on-campus work. We have canceled several overseas research presentations and meetings. Spending was less than the budget.

In fiscal 2019, due to the Corona crisis, the planned workshops on production were cancelled. Originally, American MIT, Europe and Singapore professors planned to hold a research workshop at Doshisha University, but we had to cancel it.

I also cancelled two overseas business trips (academic society).

2. Workstation:

The *seru* production design research, which is the goal of the Omron Research Project, is difficult to analyze using mathematical models with high computational complexity and will be verified through numerical simulations. In order to perform at least tens of thousands of simulations for the verification, we have changed from the originally planned high-speed computer to a high-speed workstation.