ISSN 2278-3091
Volume 10, No.3, May - June 2021
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse551032021.pdf
https://doi.org/10.30534/ijatcse/2021/551032021

Project Selection through a Simulation Model of the Painting Robots

T. Kriangkrai[1], B. Surapong[2], C. Kijcha[3], S. Khongsak[4] and A.H. Ismail[5]
[1]Faculty of Engineering, Rajamangala University of Technology Lanna, Chiangmai, Thailand, k.kriang1964@gmailmail.com
[2]Faculty of Engineering, Rajamangala University of Technology Lanna, Chiangmai, Thailand, pong_pang49@yahoo.com
[3]Faculty of Engineering, Rajamangala University of Technology Lanna, Chiangmai, Thailand, kitchar@rmutl.ac.th
[4]Faculty of Business administration, Thai-Nichi Institute of Technology, Bangkok, Thailand, khongsaksss67@gmail.com
[5]School of Mechatronic Engineering Universiti Malaysia Perlis, Malaysia, ihalim@unimap.edu.my

ABSTRACT

At present, the manufacturing sector, there is an increase in competition, emerging markets, the rise of competitors in the region and competing countries with the availability of wages creating an impact on the contractors in terms of cost, quality and production capability which makes the production model in use today. There is a need to adjust to enhance competitiveness with regional and global competitors. And automated production lines are normally used in industrial production systems. Rather, it is often a large-scale entrepreneur or from a relocation or automated manufacturing technology that comes with the start-up. Robotic automation has long been used to replace human workers for tasks having a high degree of risk, such as areas with high heat, hazardous chemical area. The use of robots particularly in industrial painting not only protect human health but also improve the productivity. The robot can work continuously without being tired is an advantage compared to human workers. The investment in the robotics project for manufacturing is quite high in the initial period. Often the inventor will need to ensure that their investment is worth for which the robotics system to be used at full capacity. Decisions on an investment involve many intangibles that need to be traded off. In this study, the painting robot production process was simulated and analyzed to how to improve the capacity of the painting robots. FlexSim is used to analyzed and simulated to optimize the painting robots. In summary, the simulation shows the productivity of a proposed production is more than current production 2.47 times. While the capacity increasing 2.97 times.

Key words: Simulation, productivity improvement, motion and time study, project selection, pairwise

1. INTRODUCTION

The background and the idea of increasing productivity started with the use of scientific concepts in management. Emphasizing that scientific management principles wanted to change the attitude of both employees and the management that saw the need to use science principles to manage to drive productivity requires cooperation from different groups of people, employers, workers and the general public. Because the increase in productivity is beneficial for individuals in different groups, and the participation of all parties to drive productivity and the benefits that arise were distributed equally which is the basic principle of increasing productivity. There are 4 cases to consider increasing productivity:

- Productivity increases the factor of increasing the same.
- Productivity increases, inputs decrease.
- Same product but inputs decreased
- Increased productivity and inputs but the inputs increase at a lower rate than the increase in productivity.

The industrial robots specifically painting robots were created to keep workers out of "dangerous" jobs as well as increase productivity and maintaining quality. Painting Robots have been invented over 30 years, can be found explicitly in the automotive industries. Painting robots are used by vehicle manufacturers to do detailing work on their cars in a consistent and systematic way. Almost production process of the ceramic factories also exposed to uncomfortable environment specially for a lot of dust. The application of the robots is quite significant in this industry since robot application can achieve consistent product quality, continuous operation and controllable operation cost. However, high investment cost on the robotic application is one of disadvantages. To make a decision on the investment we need to know the problem, the need and purpose of the decision, the criteria of the decision, their sub-criteria, stakeholders and groups affected and the alternative actions to take. We then try to determine the best alternative, or in the case of resource allocation, we need priorities for the alternatives to allocate their appropriate share of the resources [1]-[4].

Therefore, the management and engineers must carefully study the information of the project in order to demonstrate the effectiveness of the robots, including the provision of relevant information such as marketing and production capability to the investors, and also for the knowledge of other departments. There are many engineering conventional tools are widely used such as VSM [5], TQM [6], TPS [7], Lean [8], [9]. Simulation software [10]-[13] was interested by engineers such as Arena [14], Delmia [15], [16]. The FlexSim is 3D simulation software [17] that models, simulates, predicts, and visualizes systems in manufacturing, material handling, healthcare, warehousing, mining. The applications are wide, such as in Manufacturing:[18] production, job shop. In this research, pairwise comparison matrices and a simulation model by FlexSim are developed for analysing the painting robots of ceramic production. The criteria for comparison between current process and proposed process are capacity, throughput, productivity, as well as the number of workers.

2. CURRENT SITUATION

2.1 Painting Process Layout

The standard painting robots is used in this ceramic factory. The movement path and the painting time for each product are programming by an engineer and keep into the list of programme.

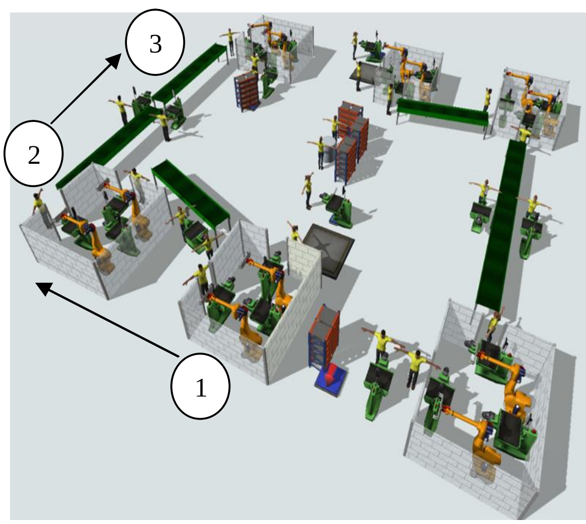

Figure 1: Simulation of Current Painting Process Layout

The operation flow of the painting process regarding to Figure 1 can be explained by Figure 2.

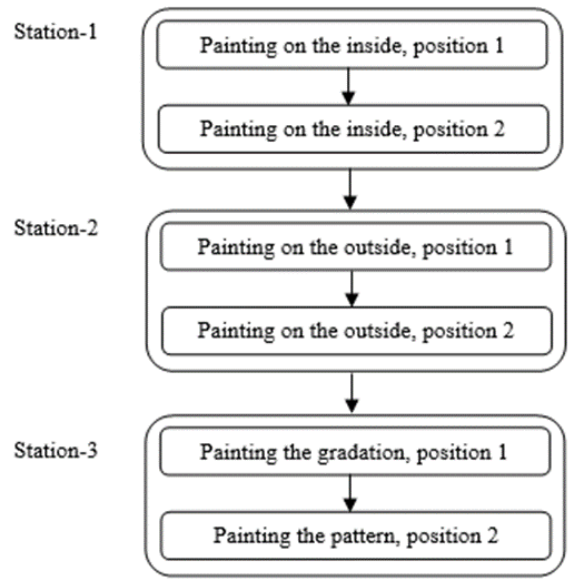

Figure 2: Operation Flow of the Painting Process

Station-1: There are 2 robots installed here. The 1st robot is using for painting on the inside, movement path no.1. While the 2nd robot is using for painting on the inside of product, movement path no.2.

The conveyer is using for transportation the pieces to the station-2.

Station-2: There are 2 robots installed here. The 1st robot is using for painting on the outside, movement path no.1. While the 2nd robot is using for painting on the outside of product, movement path no.2.

Also, the conveyer is using for transportation the pieces to the station-3.

Station-2: There are 2 robots installed here. The 1st robot is using for painting on the outside, movement path no.1. While the 2nd robot is using for painting on the outside of product, movement path no.2.

2.2 Motion and Time Study

The operation time of each job element is shown in Figure 3.

- There are 3 stations for painting the ceramic work pieces.
- Current painting station consist of 2 robots.
- There are 25 work steps.
- There are 3-step inter-process transportation
- There is a 1-step verification.
- Total cycle time for the entire process is 481 seconds per piece.
- Total travel distance 26 meters
- Ten production workers per production line per shift

Event Description	Symbol					Time (Second)	Distance (m)
Inspection	○	⇨	D	■	▽	18	
Cleaning biscuit with water.	●	⇨	D	□	▽	23	
Cleaning by water and tape on the logo	●	⇨	D	□	▽	29	
Loading product to station1	●	⇨	D	□	▽	13	2.5
Move to Robot#1-1	●	⇨	D	□	▽	5	
Spray color#1 position 1	●	⇨	D	□	▽	20	
Move to Robot#1-2	●	⇨	D	□	▽	5	
Spray color#1 position 2	●	⇨	D	□	▽	15	
Move to unloading station	●	⇨	D	□	▽	5	
Unloading the product to conveyor	●	⇨	D	□	▽	9	2.5
Move to station2	○	➡	D	□	▽	18	12
Loading product to station2	●	⇨	D	□	▽	10	
Move to Robot#2-1	●	⇨	D	□	▽	5	
Spray color#2 position 1	●	⇨	D	□	▽	23	
Move to Robot#2-2	●	⇨	D	□	▽	5	
Spray color#2 position 2	●	⇨	D	□	▽	21	
Move to unloading station	●	⇨	D	□	▽	5	
Unloading the product to conveyor	●	⇨	D	□	▽	9	2.5
Move to station3	○	➡	D	□	▽	18	3
Move to Finish by conveyor	○	➡	D	□	▽	18	3
Finishing	●	⇨	D	□	▽	94	
Loading product to station3	●	⇨	D	□	▽	10	
Move to Robot#3-1	●	⇨	D	□	▽	5	
Spray color#3 position 1	●	⇨	D	□	▽	23	
Move to Robot#3-2	●	⇨	D	□	▽	5	
Spray color#3 position 2	●	⇨	D	□	▽	21	
Move to unloading station	●	⇨	D	□	▽	5	
Unloading product and Polishing	●	⇨	D	□	▽	21	
Cleaning transfer product to car rack	●	⇨	D	□	▽	28	

Figure 3: Motion and Time Study of the Current Painting Robots

3. METHODOLOGY

3.1 Design the Concept

The process of selecting a conceptual design consists of key principles: a hierarchical framework, analysis of priorities, defining the problems used in the top-level decision-making. It represents an overall objective or goal. [105,106,107] Create evaluation level criteria, then compare them as shown following, and finally select the most appropriate alternative [108,109]. The scale of absolute numbers is,

1 is Equal
3 is Moderate
5 is Strong
7 is Very strong
9 is Extreme

Pairwise comparison matrix of the main criteria with respect to the Goal are Productivity, Capacity and required investment. Results from the management survey,

Table 1: Pairwise comparison matrix

Criteria	*Productivity*	*Capacity*	*Investment*	*Priority*
Productivity	1	5/9	5/5	2.56
Capacity	9/5	1	7/5	4.2
Investment	3/5	1/7	1	1.74

To determine the priority of the target specification by calculating from the following equation,

$$W_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_i^n a_{ij}} \qquad (1)$$

Where $i,j = 1,2,\ldots,n$

The results of the synthesis showed the priorities, the order is as follows: Capacity (4.20), Productivity (2.56) and Investment (1.74).

The next step is to make comparative comparisons at project proposal selection levels. The scale is,

1 is Equal
2 is Better

Table 2: Comparisons at project proposal selection levels

Current painting process	Proposed painting process		
	Capacity	Productivity	Investment
Capacity	1/2		
Productivity		1/2	
Investment			1/1

The full score of this table is 6 (2x3). Therefore, when the sum of Current to proposed painting process is 2, indicating that the score is not more than half of 6, it can be concluded that Proposed painting process is more suitable to be new painting process.

3.2 Production Process and Layout Design

Considering Figure 1, the greatest possibility is to add up to 6 production lines. The proposed painting process is presented on Figure 6.

Event Description	Symbol					Time (Second)	Distance (m)
Inspection and Cleaning biscuit with water	○	⇨	D	■	▽	21	
Loading product to auto spray booth	●	⇨	D	□	▽	9	
Auto spray booths	●	⇨	D	□	▽	10	
Loading product to station1	●	⇨	D	□	▽	3	
Move to Robot#1-1	○	➡	D	□	▽	37	6
Spray color#1 position 1	●	⇨	D	□	▽	6	
Move to Robot#1-2	●	⇨	D	□	▽	3	
Spray color#1 position 2	●	⇨	D	□	▽	18	
Move to unloading station	●	⇨	D	□	▽	3	
Unloading product and Polishing	●	⇨	D	□	▽	4	
CC and Transfer product to car rack	●	⇨	D	□	▽	16	3

Figure 4: Motion and Time Study of Proposed Layout for Processes

3.3 Motion and Time Study

The operation time of each job element of the proposed painting production process is evaluated. The result of this analysis is shown in Figure 7 involved 4 workers. The cycle time of this process is 130 seconds. The process's cycle time is reduced to almost 73% compared to the current practice.
Then FlexSim software is used to simulate and compare between current painting process and proposed painting process.

3.4 Simulation

The powerful and user-friendly of FlexSim 3D simulation software was use in this study. The current painting process shown in Figure 5, and the proposed painting process shown in Figure 6 are simulated and compare the results. The motion and time study from Figure 3 and Figure 4 is used to input to parameters value of the FlexSim software.

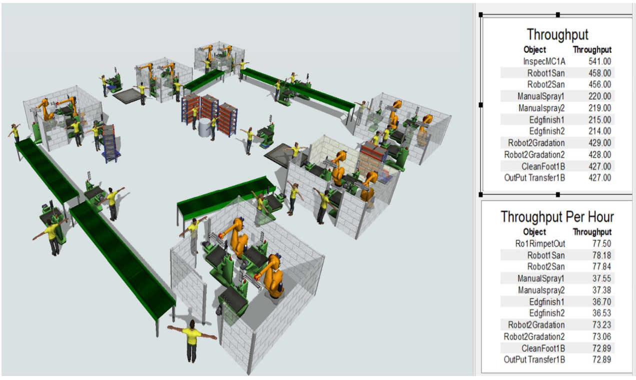

Figure 5: Simulation of Current Painting

Figure 6: Simulation of Proposed Painting

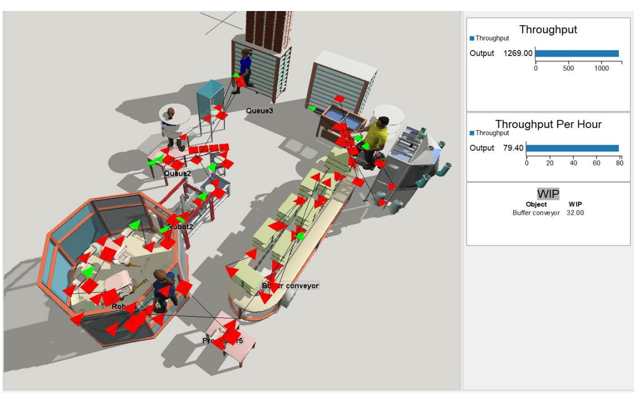

Figure 7: Simulation of Proposed Painting

Figure 7 each worker works with different duties and different operation time as shown by the motion and time study in Figure 4 which are,

The 1st Worker, task is material preparation and inspection.

The 2nd Worker, task is to operate the automated spray booth.

The 3rd Worker, task is to load workpiece to painting robots.

The 4th Worker, task is to unload workpiece from painting robots and polishing.

The 5th Worker, task is to collect the finished products and keep on the cart.

Since to spraying time of the robot is bottle neck, so 1st Worker is moved out. Finally, four workers are assigned to run the proposed painting process.

4. RESULTS AND ANALYSIS

Table 3: The Results of Current Painting Processes

Data	Current Painting Production Process
Number of production lines (lines)	2
Throughput (pieces per day)	2,562
Number of workers (persons)	66
Productivity (unit/man/hour)	6.1

Table 4: The Results of Proposed Painting Processes for Single Colour Plate

Data	Proposed Painting Production Process
Number of production lines (lines)	6
Throughput (pieces per day)	1,269x6 = 7,614
Number of workers (persons)	72
Productivity (unit/man/hour)	15.1

A. Throughput

The simulation on Figure 5, Table 3 shows the output of current production process which is 2,562 pieces/day. While the simulation result of the proposed painting production process shows in Table 4 the output equal to 1,269 pieces/day/line, for all 6 lines, daily output will be 7,614 pieces/day. The capacity of proposed painting production process equal to 2.97 times of current painting production process.

B. Productivity

Current production process layout shown in Figure 1, the number of current production workers is 11 workers/shift/line or total workers will be 66 workers per day. The proposed painting production process will use only 4 workers/shift/line. So total required 72 workers per day. Productivity of current painting production process equal to 6.1 unit/man/hour. Productivity of proposed painting production process is 15.1 unit/man/hour which is more than current painting production process 2.47 times.

C. Investment

Current capacity, the initial investment for a paint robot is 228,000 USD per station, in total 6 stations invested

1,368,000 USD. Therefore, if required capacity increase 2.97 times, required investment equal to 2,736,000 USD.

Since, the equipment using in the proposed painting production process is automated spray booth, it inexpensive when compared to painting robot. Therefore, required investment for proposed painting production process is 300,000 USD for all 6 lines.

5. CONCLUSION

In order for improvement to be successful, there must be a strong commitment to improving the productivity of the organization, whether it is the commitment and involvement of senior management. Leadership and participation of middle management, full effort of supervisors and employees, and being in a spirit of thinking, being positive all the time, strengthened their hearts in the face of problems to succeed. High investment in projects must ensure that we make the best utilization of our resources with maximum capacity. Software-based project simulations help management make confident decisions about how to invest in a project.

FlexSim simulation, the proposed painting process can generate capacity 2.97 times more than the current painting production.

ACKNOWLEDGEMENT

This works is done thanks to suggestions and recommendations from advisory boards consisting of research team, management team and staffs at the ceramic factory, who participant until the end of project completion.

REFERENCE

1. Reza E, Adel A and Kambiz J. **Identification of criteria and priority measurement of marine tourism compatibility using analytic hierarchy process**, International Journal of Advanced and Applied Sciences, pp.98□106, 2016.
2. Ahmad Rifai Sarraj and Raphael Massarelli. **Design History and Advantages of a New Lever-Propelled Wheelchair Prototype**, Int J Adv Robotic Sy. Vol. 8, No. 3, pp.12-21, 201.
3. Saaty, Thomas L. **Decision making with the analytic hierarchy process**. International journal of services sciences, pp.83-98, 2008.
4. T.S.Safarov et al. **Methods and Models of a Multifunctional System Support for Decision Making for Differential Diagnosis of Diseases**, International Journal of Advanced Trends in Computer Science and Engineering, 9(3), pp. 3350 – 3353, May – June 2020.
5. R.M. Belokar, Sandeep Singh Kharb and Vikas Kumar. **An Application of Value Stream Mapping In Automobile Industry: A Case Study**, International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume 1, ISSN: 2278-3075, pp.231 – 236, 2012.
6. Salleh Noor Azlina Mohd, Salmiah Kasolang and Ahmed Jaffar. **Simulation of Integrated Total Quality Management (TQM) with Lean Manufacturing (LM) Practices in Forming Process Using Delmia Quest**, Procedia Engineering 41, pp.1702 – 1707, 2012.
7. Monden, Y. **Toyota production system: an integrated approach to just-in-time**, Industrial Engineering and Management Press Ohno,T.,1988.Toyota Production System: Beyond Large Scale Production. Productivity Press, Cambridge, pp.1 – 110, 1993.
8. Hanane RIFQI et al. **Lean Facility Management 4.0: A Case Study**, International Journal of Emerging Trends in Engineering Research, 8(10), pp. 7363 – 7370, October 2020.
9. Fairul Anwar A B et al. **Lean Six Sigma Implementation on Reducing Incoming Processes Time in QA Department at Reckitt Benckiser Sdn Bhd**, International Journal of Advanced Trends in Computer Science and Engineering, 9(1.1), pp. 252 – 258, 2020.
10. B. J. Schroer. **Simulation as a Tool in Understanding the Concepts of Lean Manufacturing**, **SIMULATION**, Vol. 80, Issue 3, pp. 171-175, 2004.
11. J. H. Marvel and C. R. Standridge. **A simulation-enhanced lean design process**, Journal of Industrial Engineering and Management Vol. 2, Issue 1, pp. 90-113, 2009.
12. J. W. Fowler, and O. Rose. **Grand Challenges in Modeling and Simulation of Complex Manufacturing Systems**, SIMULATION Vol. 80, Issue 9, pp. 469-476, 2004.
13. C. Liong and S.E.C. Loo, **A simulation study of warehouse loading and unloading systems in Arena**, Journal of quality measurement and analysis, Vol. 5, Issue 2, pp. 45-56, 2009.
14. John, B. and E. Jenson Joseph. **Analysis and simulation of factory layout using ARENA**, International Journal of Scientific and Research Publications, 3(2), pp.1 – 8, 2013.
15. Elena-Iuliana Gingu and Miron Zapciu. **Improving layout and workload of manufacturing system using Delmia Quest simulation and inventory approach**, International Journal of Innovative Research in Advanced Engineering (IJIRAE), Volume 1, Issue 6, pp.52 – 61, July 2014.
16. Norhidayah M., Yupiter H.M., Roseleena J., Shaharudin A. and Erry Y.A. **Development of virtual assembly layout with modeling languages approach and Simulation using Delmia Quest**, IIUM Engineering Journal, Vol. 12, No. 6, pp.9 – 20, 2011.
17. Erol Gelenbe and Hatim Guennouni, **FlexSim: A flexible manufacturing system simulator**, European Journal of Operational Research, Volume 53, Issue 2, pp.149 – 165, July 1991.

18. U.Sravan Kumar and Shivraj Yeole. **Productivity Improvement through Optimization of Layout using Flexsim Simulation Software**, 5th National Conference on Advances in Mechanical Engineering, At Vasavi College of Engineering, Hyderabad, Volume: 01, pp.64 – 67, May 2015.