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A Modelling and Analysis Approach through Robot Simulation Tools and Break-Even Analysis for an Automated CANs Packing Production

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ABSTRACT

Robotic automation has long been used to replace human workers for tasks that carry a high degree of risk, such as areas with high heat, hazardous chemical area. Not only do industrial robots protect human health, but they also improve productivity. The investment in the robotics project for production is quite high at first period. Investors will be sure that the robot will be used at full capacity. Therefore, the application of robot simulation software is presented in this paper. The metal can manufacture industry is used as a reference in this paper. Motion and Time study is used to measure the operation working flow and cycle time of current aerosol can packaging and palletizing. The proposed system which uses a robotic combined with an automated packaging machine are also established. The indicators such as productivity and utilization are simulated by the MATLAB software by using the Fuzzy Logic analysis. DELMIA is a simulation software to present a detail of design phase of the production process. While the amount of the order must be sufficient when compared to the investment. In this paper, break-even points of the robot application determined.

Key words: Robotic, Modelling, DELMIA, Palletizing, Break-Even Point

1. INTRODUCTION

Present, there are many applications of the industrial robots, for instance the forming process, handling process, and packing process as well as the use of robots for palletizing process. Robot operation can achieve consistent product quality, continuous operation and operation cost controllable. However, high investment cost on the robotic application is one of disadvantages. Therefore, the management and Engineers must carefully study the information of the project in order to demonstrate the worthwhile use of robots. To provide information to investors and other departments to understand, such as marketing and production.

Digital Manufacturing, whether it is computer technology or whether it is in the application of various applications that help the production and design develop rapidly and with precision. This will help reduce errors that will occur from the work of people. Therefore, the 21st century is the era of bringing Digital to change the face of various industries [1]. Design and development products with Digital Manufacturing System nowadays, it is widely used in industries such as automobiles, food, power, electronics, medical, fashion, etc. [2],[3].

DELMIA [4] is a digital manufacturing tool for driving innovation in production planning to be efficient in digital format. To create Simulation of the production process at the combined act level. It enables manufacturing companies to simulate production processes based on their hands-on experience in factories. Used to determine how to work, improve the problem. Including the effects that may occur to meet the needs of consumers around the world. This virtual production simulation allows manufacturers to optimize their workflow. It responds quickly to new competition and market opportunities.

In this paper, the cans manufacturing industry for containing beverage and ink are case study. The changes of an operation to automate is required for achieving the target of cost and delivery. The fuzzy logic [5], [6] approach is applied to investigate the proposed production process. By offering the benefit of productivity and utilization.

For investment decision making point of view, an engineering economic tool such as net present value, payback period or break-even analysis [7] are other indicators commonly used in determine profit specially for projects that require a large investment. The break-even analysis is a very useful tool for a good estimation for return on investment. Its goal is to find the point, in this case in terms of cash and units, where investment costs equates profits. Above this point the business begins to obtain profitability [8]. Managerial decisions require a careful analysis of the behavior of costs and profits. In these cases, the break-even linear model is widely used. Both revenue and total costs are assumed to be linear in this model, i.e. the price and the variable cost per unit are constants. The uncertainty is considered implicit [9], [10].

2. CURRENT SITUATION

2.1 Aerosol CANs Packaging and Palletizing Process

In this study, motion and time study of current production process of aerosol cans, in which the process of packaging 12 aerosol cans into a cardboard carton and palletizing manually manufacturing scenario by employs workers as shown in Figure 1

Motion and Time study

		Summary			
Location : Packing and palletzing		Event	Present	Proposed	Saving
Activity : Can		Operation	100		
Date : 18-Oct-19		Transport			
Operator :	Analyst :	Delay			
Method and Type :		Inspection			
Method : (Present) Proposed		Storage			
Type : (Operator) Material Machine		Time (sec)			
Yeild :		Distance (m)			
Mat.Margin (%) :		Cost			

Event Description	Symbol: Operation	Transport	Delay	Inspect	Storage	Time (Second)	Time (Second)	Time [Second]
Cardboard carton forming	●	⇨	D	□	▽	15		
Partition assembling	●	⇨	D	□	▽	20		
Putting an assembled partition	●	⇨	D	□	▽	10		
Carton preparing	●	⇨	D	□	▽	10		
Aerosol cans packaging	●	⇨	D	□	▽	30		
Palletizing	●	⇨	D	□	▽	15		

Figure 1: Motion and Time Study of the Current Packing and Palletizing Production

The process flow chart of packing and palletizing production is shown in Figure 2.

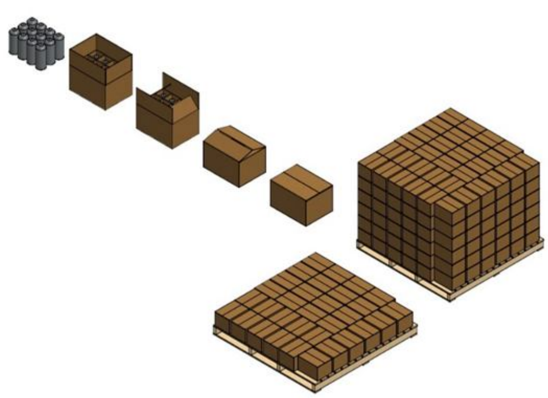


Figure 2: Process Flow Chart of Packing and Palletizing Production

Figure 3: Forming

Station1: Forming a cardboard carton and assembling a 12 compartments partition, and then putting an assembled partition into the cardboard carton, with three workers presented in Figure 3.

Figure 4: Assembly

Station2: Assembly station, with one worker, and other one worker packaging the aerosol cans in a cardboard carton and sealing it presented in Figure 4.

Figure 5: Palletizing and Sealing

Station3: Palletizing station, with one worker presented in Figure 5.

2.2 Current Workcell Analysis

The motion and time study of current packing and palletizing process are measured. Since current process is manually operation, so cycle time will be presented as human cycle time (CT) which is,

$$CT = \sum_{i=1}^{n} t_i \qquad (1)$$

where CT is cycle time, sec/pa; t_i is material handling/assembly operation time at workstation i, sec; i = workstation.
The production rate (R_p) of a human workcell can be illustrated as in (2):

$$R_p = \frac{60}{T_p} \qquad (2)$$

where R_p is work units/hour, pa/hr; T_p is the longest production time/work unit, min.

It is seen that the cycle time of a human workcell for packaging aerosol cans in one pack, and then palletizing, can be obtained from (1), therefore,

$$CT = 15+20+10+10+30+15 = 100 \text{ sec}$$

Production time per work unit on the workstation that takes the longest is,

$$T_p = 30 \text{ sec} = 30/60 = 0.5 \text{ min}$$

Calculate the production rate from (2) will be:

$$R_p = \frac{60}{0.5} = 120 \text{ pas/hr}$$

3. DEVELOPMENT METHODOLOGY

3.1 Design the Concept

Current production flow is,

- Station 1: Provided the aerosol cans in 12 cans pattern per group by workers.
- Station 2: Put a group of aerosol cans into a carton by workers,
- Station 3: Sealing the carton by worker.
- Station 4: Palletizing the sealed can as shown in Figure 6.

All the steps of operation are manually operation.

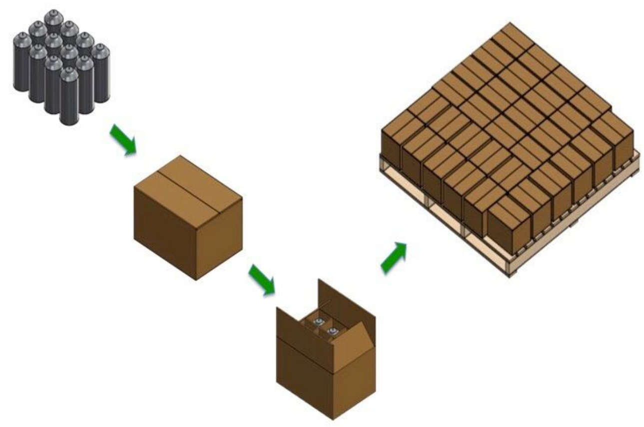


Figure 6: Design the Concept of Packaging to Palletizing Process

3.2 Analysis of CANs Packaging Cell

The fuzzy model for production rate is shown in Figure 7. There are three inputs, transferring rate (Tr), packaging rate (Pk) and palletizing rate (Pl), and one output fuzzy variable, production rate (Rp) are considered. The membership functions for each fuzzy set are triangular except at the extreme left are assumed. Universe of discourse of the variables is defined as:

Tr = [0.8, 16]
Pk = [0.0, 15]
Pl = [0.0, 16]
Rp = [0.0, 20]

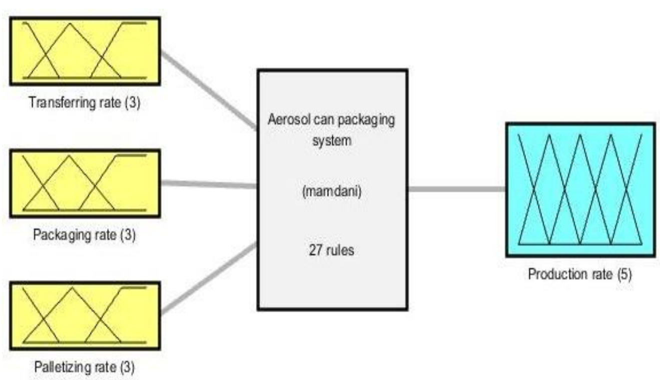


Figure 7: A Fuzzy Model

When entered the parameters for each three inputs to MATLAB software in Fuzzy logic, a crisp output of the production will be presented as shown in Figure 8.

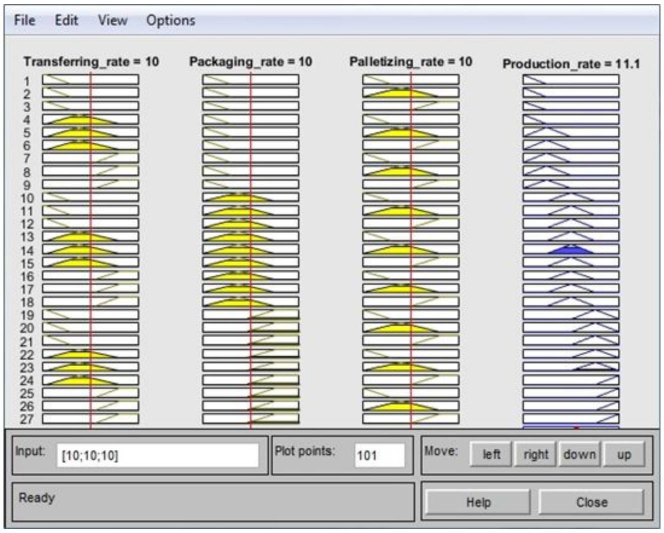


Figure 8: Output Rate of Production

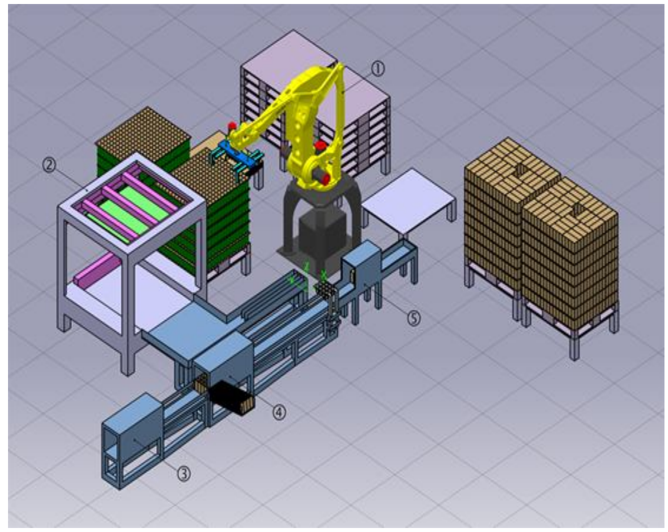


Figure 9: Robotic Modelling and Working Stations

3.3 Robotic Workcell Modelling

Delmia V6 software was used for developing the conceptual design for proposed system following steps are:

1. A joint arm robot:
   a) Picks cardboard.
   b) Places it on the cardboard stack.
   c) Then moves back to pick an empty pallet
   d) Place it on the support base.

2. An automatic can transferring machine:
   a) To loads 228 aerosol cans at a time.
   b) Then transfers them to the end of the feed track.

3. The cardboard will be folded in this automatic case erector then the assembled cardboard carton is transported to the end of conveyor, wait for packaging.

4. The joint arm robot:
   a) Picks 12 aerosol cans.
   b) Moving to the conveyor.
   c) Places all the cans in the carton.
   d) The aerosol canned carton is then conveyed to an automatic carton sealer to seal this carton using tape.

5. The joint arm robot moves to pick the sealed carton one by one, then do the palletizing.

3.4. Simulation

The geometric modeling and kinematic analysis [11] are simulated the movement of a robotic and automated machines. It shows the Gantt chart of the joint arm robot in each activity only throughout the cycle time, which is 554.97 sec, as shown in Figure 10 (a), (b), and (c).

4. ANALYSIS OF ROBOTIC WORKCELL

4.1. Robot Cycle Time Analysis

The total time of process [12] is equal to robot cycle time shown in Figure 10 (a), (b) and (c). The cycle time of the proposed production process consist of palletizing, de-palletizing, machine loading and unloading system. The cycle time determine by,

$$T_c = T_o + T_h + T_w \qquad (3)$$

where T_c is cycle time, min/pa; T_o is time of the actual palletizing/de-palletizing, machine loading/unloading operations, min/pa; T_h is work part handling, min/pa; and T_w is average waiting time, min/pa.
All activities time can be classified into 5 groups of activities, as shown in Table 1.

Table 1: The Activities of the Robotic Manipulator for 19 packs of Aerosol CANs Packaging and Palletizing.

Operation	Time
1. De-palletizing	10 seconds
2. Material handling	20 seconds
3. Packaging (19 times)	171.19 seconds
4. Unloading (19 times)	95 seconds
5. Palletizing (19 times)	258.78 seconds

The cycle time, T_c can be calculated from (3),

$$T_c = 10+20+171.19+95+258.78 = 554.95 \text{ sec}$$

$$= 9.25 \text{ min/19 pas}$$

The production rate of a robotic process included the time to set up of the process,

$$T_p = \frac{T_{su} + Q_{Tc}}{Q} \qquad (4)$$

where T_p is an average production time/work unit, min; T_{su} is setup time, min; and Q is quantity of work units produced in the production run.

Production rate is the reciprocal of average production time:

$$R_p = \frac{60}{T_p} \qquad (5)$$

where R_p is work units/hour, pa/hr. For long-running jobs, R_p approaches the cycle rate R_c, which is the reciprocal of T_c. That is, as Q becomes very large $(T_{su}/Q) \rightarrow 0$ and

$$R_p \rightarrow R_c = \frac{60}{T_c} \qquad (6)$$

where R_c is operation cycle rate of the machine, pa/hr; T_c is the longest operation cycle time, min/pa, which is,

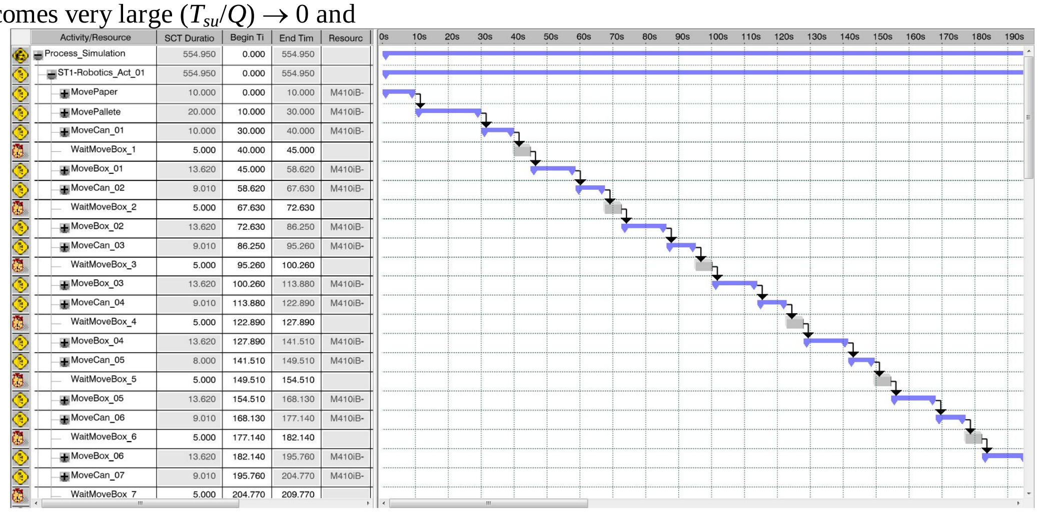
$T_c = 27.63/60 = 0.46$ min

5. CALCULATE THE PRODUCTION RATE FROM (6),

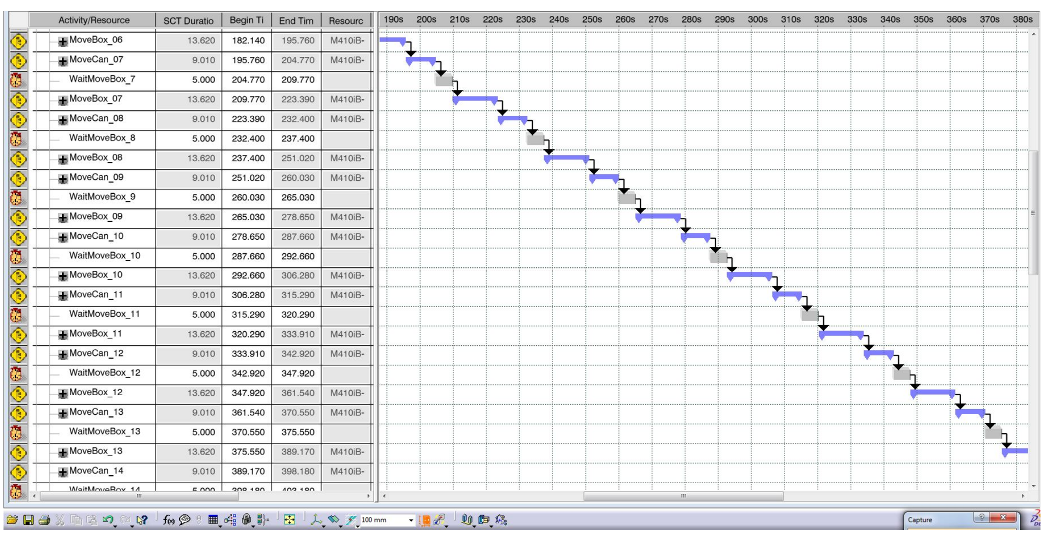
$$R_p = \frac{60}{0.46} = 130.43 \approx 130 \text{ pas/hr}$$

However, from the fuzzy logic model the production rate increase by approximately 4 times, Thus,

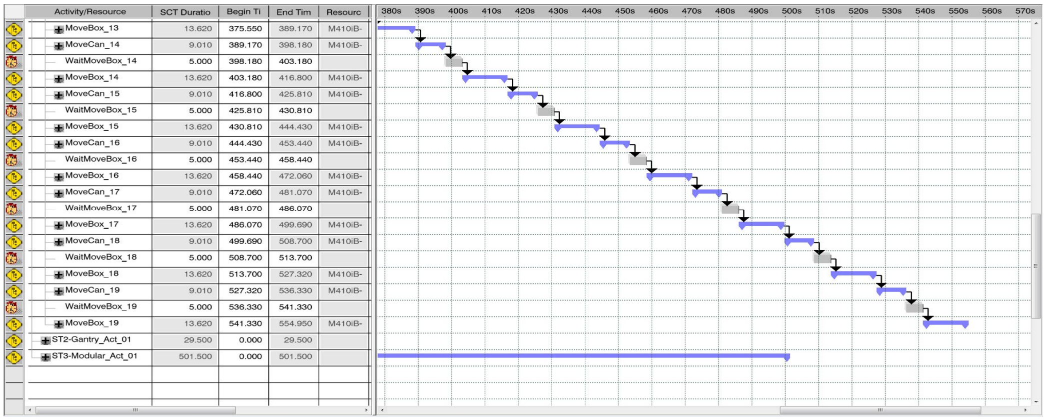
$R_p = 130.43 \times 4 = 521$ pas/hr



(a)



(b)



(c)

Figure 10: Robotics Gantt Chart (a) Duration 0-190s, (b) 190-380s, and (c) 380-555s

Table 2: The Performance of Aerosol CANs Packaging and Palletizing Workcells for Product Demand equal to 273,600 packs.

Workcell	Cycle time (sec)	Production rate (pa/hr)	Total time (hr)	No. of worker (person)
Manual packaging palletizing	100	120	2280	6
Automated packaging palletizing	29.21	521	525	none

4.2 Analysis of Results

From Table 2, the production rate of the proposed production press is 1.42 times higher than current production process for both packaging and palletizing which is increased from 120 pas/hr to 521 pas/hr.

4.3 Break-Even Analysis

The break-even point is the point where the business's sales have generated enough income to cover total of fixed costs and expenses. Formula,

Contribution per unit = $P - VC$ *(7)*

Where,
P is Revenue per pallet
VC is Variable cost per pallet

$$BEP = \frac{FC}{P - VC} \quad (8)$$

Where,
BEP is break-even point in quantity
FC is fixed costs

Decisions, the break-even point identifies the total amount of benefit the packaging and palletizing production process needs before profit can be earned.

In this study we considered,
Constraints,

- The variable cost was considered only direct labor cost which was estimated at 4.00 USD per man-hr.
- The fixed costs of current packaging and palletizing production were estimated at 20.00 USD per hr.
- The revenue of packaging and palletizing production is 0.50 USD per pallet.
- Initial investment cost of proposed packaging and palletizing production is 210,000 USD.
- Operation cost of proposed packaging and palletizing production is 22,000 USD per year.

From the revenues and costs data above, by input the value into (7) be able to know the break-even point of the packaging and palletizing production of this factory.

Break-even analysis
Determined the value of each variables, found
FC1 is fixed cost of current for packaging and palletizing production was calculated depreciation at 5 years, working hours 8 hours per day and 26 working day a month. So the fixed cost of packaging and palletizing is,
FC1 = 20 x 8 = 160 USD/day

FC2 is fixed cost of proposed for packaging and palletizing production is,

FC2 = 210,000 / (5 x 12 x 26) = 134.6 USD/day
VC1 is variable cost of current packaging and palletizing production. Total woker is 6 with 1 shifts operation.

VC1 = (4.0 x 6) / 120 = 0.20 USD/pallet

VC2 is variable cost of proposed packaging and palletizing production is,

VC2 = 22,000 / (12 x 26 x 8 x 521) = 0.017 USD/pallet

From (8) and information we have,

BEPcurrent = 160 / (0.50 – 0.20) = 533 pallets per day

BEPproposed = 134.6 / (0.5 – 0.017) = 279 pallets per day

From calculation results presented that BEP of the current packaging and palletizing production is 55.56% of the maximum capacity. While BEP of the proposed packaging and palletizing production is only 6.70% of the maximum capacity which is quick opportunity to make profit.

5.CONCLUSION

The results of a modelling and analysis through robot simulation presented, the production rate of the proposed production process applied robotic is higher than current manually production process 4 times. Break-even of the proposed system was also presented quicker to make profit.

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