PERT-Type System Application on Food Industry to Reduce CIP Cycle Time

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Abstract

Clean in place (CIP) is in site cleaning activity with a purpose to eliminate soils, preventing cross contamination and food decomposition by bacteria. Hence, CIP activity is a critical step in food processing industry. Unfortunately such activity is considered non-productive because it does not produce any finished goods, so CIP needs to be done in minimum time. This study aimed to describe and analyze implementation of PERT-type system model in order to reduce CIP cycle time in food industry. Research data is obtained from historical data of related party in production situation, with a focus of CIP cycle activity. Observations were also conducted directly on the object of study. Methodology approach began with non-productive dominant factor sorting, CIP activity elements identification, standard time data acquisition based on secondary data then followed by time reduction using a PERT-type system in heuristic manner. The results showed that CIP cycle time reduction could be achieved from the initial state of 330 minutes to 180 minutes per cycle.

Keywords
network model, PERT, heuristic

1. Introduction

Network modelling is one of most used form of modelling in operation research because of its wide application and flexibility in practical situations. The width of its application often is implemented in business situation to increase productivity (Beer, 1967). Critical path map (CPM) as well as program review and evaluation technique (PERT) are special network model algorithm that is used as decision support system (DSS) (Trietsch & Baker, 2012). CPM is implemented to sequence a network of activities in deterministic time environment, while PERT model deals with activities in stochastic condition (Frederick & Lieberman, 2010; Supranto, 2006). More recently, the PERT and CPM systems have been combined into PERT-type system (Leitch, 1989). This system uses the fundamental network diagram to graphically depict sequential nature of activities. Such system rises in uses as one of important tools in industrial situation (Mazlum & Guneri, 2015; Puvanasvaran, 2013). Hence, in a production system, PERT-type system can be implemented to map activities network. In a cyclic production operation, each type of activity involved will repeat in a similar manner in term of times and sequence. These characteristics fulfill the requirements of using PERT-type system model to map the network, provided each activity is interdependent, running in sequential manner with known duration so the critical path could be identified (Turner, 1993).
Based on observation in food processing industry, there is a machinery and equipment cleaning phase known as CIP (*clean in place*). CIP is a necessary yet non-productive task of cleaning and sanitizing process equipment to prevent soils and bacterial contamination due to food processing in a long run, or to prevent cross contamination in different product processing (Fryer, 2005; Ryther, 2014). This activity is cyclic and comprised of several element of interdependent activities with certain duration of time to finish the task. These elements build a sequence of activity with a certain order of execution, and must be done is such sequential order to be finished. Since CIP solely concentrates on process cleaning, it does not produce any value added goods and must be done in as minimum time as possible. Moreover based on observation, the total duration of one CIP cycle is 330 minutes. Such cycle repeats in average of 14 times a month. This total average monthly time of 4620 minutes became Pareto dominant factor of

downtime loss and should be reduced and conversed to productive time, by means of reducing the total elapsed time per CIP cycle. The unrestricted time then can be used to produce value added goods.
A study of process setup reduction had been done by Puvanasvaran (2013) using CPM/PERT method. Specifically, Puvanasvaran (2013) used CPM/PERT analysis to reduce process setup time by identifying critical path and balancing time duration range on each path. This article will show an application of PERT-type system to reduce a cyclic operational condition of CIP activity.

2. Experimental Details

In this study, primary data was obtained based on observation in CIP condition. Secondary data was extracted from historical data in latest 6 month of running CIP. Data population was cycle time of CIP activity and each individual activity involved in CIP. Duration (elapsed time) for each element of activity in CIP is a secondary standard time. In one cycle of CIP there are several interdependent activities taking place. Observation was done to determine the initial sequence of CIP until end point of the cycle. See table 1 below for detailed data of the activities and its associated duration at initial state.

Table 1. Detailed Activity Data on Initial State

Activity Identity	Predecessor	Duration (minutes)	Critical Path
1	16	60	
2	1	15	
3	2	15	
4	3	30	
5	-	45	
6	5	45	
7	15	45	Yes
8	7	90	Yes
9	6,21	45	
10	9	45	
11	-	75	
12	1,11	15	
13	12	90	
14	15	75	
15	4,13,19,20,26	60	Yes
16	-	75	Yes
17	16	60	Yes
18	17	60	Yes
19	11,25	90	
20	18	75	Yes
21	15	15	Yes
22	21	45	Yes
23	22	75	Yes
24	8,10,14,23	30	Yes
25	1	0	
26	25	30	
27	15	45	

For each activity element, there's a human operator (resource) involved in getting the task done. Hence, an operator is resource constraint that determines activity sequencing. A network of PERT-type system was made to represent the connection between activities with operators performing them at any given time. Two entirely different activities in nature (location, equipment and movement) cannot be done in parallel by same operator. Though otherwise, two operators can do same activity together at the same time to reduce activity duration, provided it is practically possible. Time validation was done in one cycle of CIP, with initial cycle time of 330 minutes. This cycle time was

recorded and preserved in historian database. The initial condition critical path was either in activities line 16-17-18-20-15-7-8-24 or in activities line 16-17-18-20-15-21-22-23-24.
Time reduction was implemented on one or more activity element in CIP activity network. The implementation took a form of equipment reengineering, administrative change like resource reallocation, procedural improvement, or activity resequencing. The later was demonstrated by Koo (2007) in his study of resequencing activity in CPM model. Desired CIP cycle time was determined by external party. Improvement iteration was continually done until desired CIP cycle time achieved. Heuristic approach to reduce setup time was used in this study. Hence, although an actual time reduction was taking place, optimality is not guaranteed on solving CPM problem in heuristic manner (Leu and Yang, 1999; Leu et. al. 1999). There was no time/cost trade-off being considered on reducing the path line, since it is impractical to estimate the probable cost incurred on implementing process improvement on each activities.

3. Results and Discussion

Observation result indicated there were 27 individual and interdependent activities forming a network of CIP sequence. Each activity is done by at least one operator, with two different activities cannot be completed under the same time by one operator, e.g. parallel. These operators are spread on three different production zones; operator A occupies zone 1, operator B occupies zone 2, and the rest occupies zone 3. At initial condition (fig. 1) there were a total 5 operators occupying the production facility. The entire duration of initial CIP network was 330 minutes.

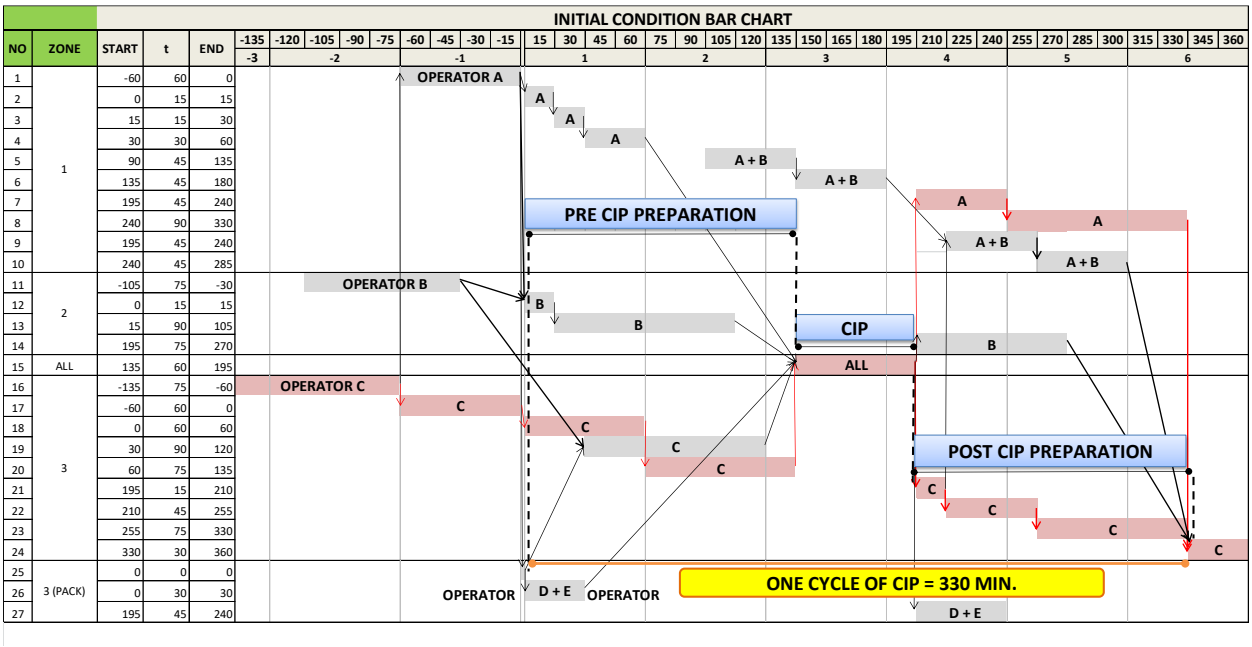

Figure 1. CIP initial condition bar chart

In initial state, activity starts at -135 minutes (activity 16); a negative time marker. Activity 16 marks as a production stop, but finished goods packing still continues until minute - 0. CIP timer starts at minutes 0 of finished goods pack stop (activity 25), entering a pre-CIP preparation time counter (marked on blue bar as 'pre CIP preparation'). This can be explained as follows: CIP is a non-productive time which does not produce value added goods. Determining productive and non-productive time depends on how such definition could be of use in process improvement and pictures a practical process condition. At initial condition (fig. 1), it would need 135 minutes from production stops until there were no valued added goods produced at all. Thus, the 135 minutes before pre CIP preparation was counted as productive time. After a total stop of finished goods packing (activity 25) at minute – 0, non-productive time counter starts. This non-productive time counter ends at activity 24, where production started up at minute - 330. Identified critical path of initial condition were marked as red bar. These activities became central focus for process improvement and balancing.
An iterative approach of process improvement was done on all side of operations. An activity with reduced duration (t) value is marked with '()' on final bar chart. First there was waste movement elimination by means of SMED and

resequencing on activity 17 and 18. Activity 21 was eliminated. Work specialization was implemented for all operators on all zones by means of work division and work load distribution. Standard operational procedure (SOP) change allows resequencing of activity 5 and its successors, activity 2 and 12. An additional human resource further allows resequencing of activity 18, 19, 20, 22 and 23. A reengineering approach on equipment was done allowing an elimination of activity 21 and simplifying predecessor for activity 9. These changes in all successfully reduced CIP cycle time from 330 minutes to 180 minutes (fig. 2).

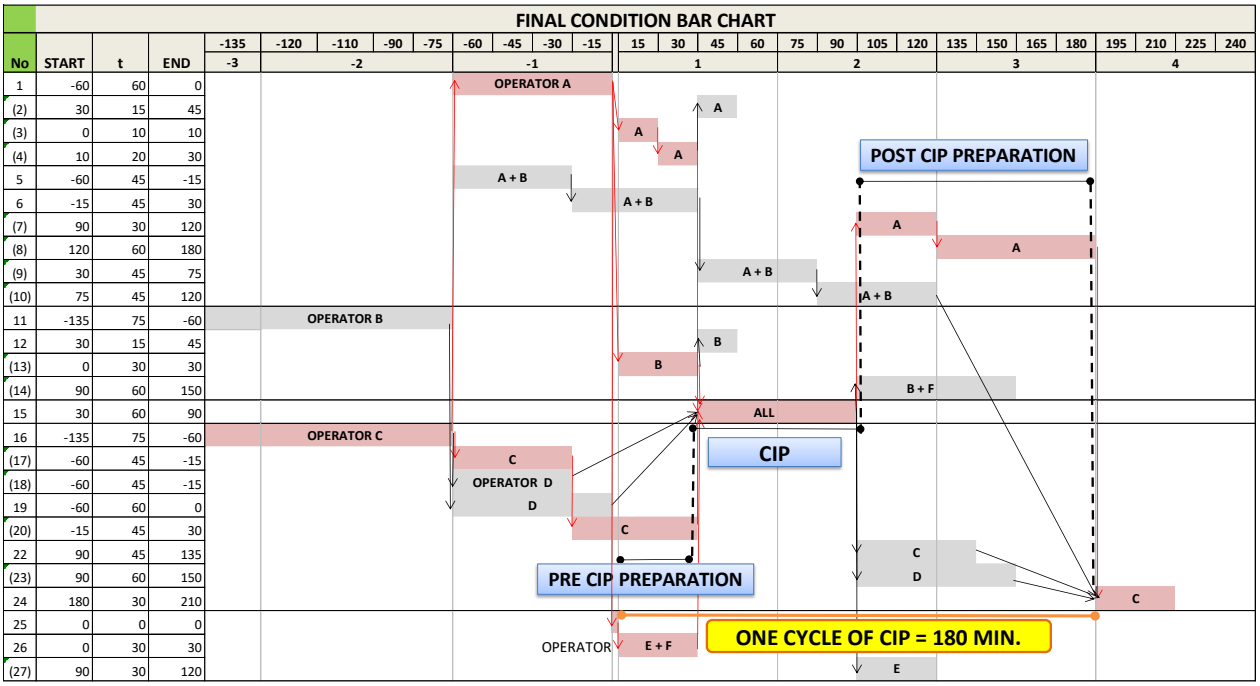

Figure 2. CIP final condition bar chart

A comparison of activity duration on initial state against final state is presented in table 2.

Table 2. Detailed Activity Comparison

Activity Identity	Initial State Predecessor	Intital State Duration (minutes)	Critical Path	Final State Predecessor	Final State Duration (minutes)	Critical Path
1	16	60		16	60	Yes
2	1	15		4	15	
3	2	15		1	10	Yes
4	3	30		3	20	Yes
5	-	45		-	45	
6	5	45		5	45	
7	15	45	Yes	15	30	Yes
8	7	90	Yes	7	60	Yes
9	6,21	45		6	45	
10	9	45		9	45	
11	-	75		-	75	
12	1,11	15		13	15	
13	12	90		1	30	Yes
14	15	75		15	60	
15	4,13,19,20,26	60	Yes	4,13,18,19,20,26	60	Yes
16	-	75	Yes	-	75	Yes
17	16	60	Yes	16	45	Yes

Table 2. Detailed Activity Comparison (*continued*)

Activity Identity	Initial State Predecessor	Intital State Duration (minutes)	Critical Path	Final State Predecessor	Final State Duration (minutes)	Critical Path
18	17	60	Yes	16	45	
19	11,25	90		11	60	
20	18	75	Yes	17	45	Yes
21	15	15	Yes	- (eliminated)	45	
22	21	45	Yes	15	60	
23	22	75	Yes	15	30	
24	8,10,14,23	30	Yes	8,10,22,23	0	Yes
25	1	0		1	30	Yes
26	25	30		25	30	Yes
27	15	45		15	60	

4. Conclusion

In conclusion, a PERT-type system approach can be implemented to reduce setup time in production system. This network analysis provides a measurement background to identify major sources of process bottleneck, especially if it consists of large network of activities. Combined with other techniques such as SMED, administrative change, work simplification and division, and equipment reengineering, a non-productive setup time can be reduced though optimality is not guaranteed. Compared to mathematical model on addressing CPM, this combined heuristic approach provides a more practical solution in industrial settings, where fast identification of process bottleneck is the essence of rapid improvement implementation. Decision makers then could react accordingly to manage and improve/reduce duration of critical path activities.

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