Proceedings of the 2013 Winter Simulation Conference
R. Pasupathy, S.-H. Kim, A. Tolk, R. Hill, and M. E. Kuhl, eds

MFCA-BASED SIMULATION ANALYSIS FOR PRODUCTION LOT-SIZE DETERMINATION IN A MULTI-VARIETY AND SMALL-BATCH PRODUCTION SYSTEM

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ABSTRACT

In the modern manufacturing industry, environmental considerations are part of numerous phases of production. Inappropriate production lot-size determination can generate substantial scrapped overdue stocks and idle processing, which lead to serious environmental burdens. In this paper, by simulating the Pull mode and back scheduling of a multi-variety and small-batch production system, large overstocks and other wastes caused by current production lot-size determination are traced. For comparison with the conventional cost accounting used in the original simulation model, a new environmental management accounting method, Material Flow Cost Accounting (MFCA), is introduced to identify negative products cost related to environmental impacts hidden in the production processes. After sensitivity analysis by gradually regulating the production lot-size, two regular changes in the negative products cost and the corresponding percentages in the total cost are observed. These change trends indicate that a reasonable determination strategy for production lot-size can improve both economic and environmental performances.

1 INTRODUCTION

1.1 Environment-Oriented Research in Production System

The main objective of company activities is to maximize economic efficiency. Ecological environmental benefit has thus often been ignored because measures related to environmental preservation cause high operation costs (Tang and Takakuwa 2012). However, in the modern advanced manufacturing industry, the idea of green production has become increasingly important as part of sustainable development. It reflects a new production paradigm that employs various green strategies and techniques to achieve greater eco-efficiency (Ahmed 2011). In green production systems, achieving zero emissions and reducing the environmental burden from production activities are thus important worldwide.

In a multi-variety and small-batch production system, it is recognized that an appropriate determination of production lot-size for different part types in different production stages is a complex problem (Azaron et al. 2009). This complexity can easily lead to serious environmental problems with limited production resources. Because of inaccurate determinations, overstocks of unnecessary materials and intermediate products are often produced, causing huge material waste, idle energy consumption and stock scraps, which create substantial environmental burden. Therefore, analyzing and determining an appropriate production lot-size to achieve both economic and environmental effectiveness are an important issue in the production research field that urgently needs to be solved.

Recently, some new accounting methods related to environmental protection have been developed and praised as a means of improving economic efficiency while reducing environmental burden. Material Flow Cost Accounting (MFCA), especially, has received considerable attention for its effectiveness in improving both productivity and the harmony of environmental profitability (Nakajima 2009). Moreover, the MFCA standard has been granted ISO 14051 by the ISO secretariat to evaluate the environmental performance of the target production processes (Environmental Industries Office 2010). Consequently, in this paper, MFCA is introduced to study the environmental impacts of production lot-size determination through structuring simulation models in a multi-variety and small-batch production system. By applying MFCA, significant invisible wastes (called "negative products" in MFCA) caused by inaccurate determinations of production lot-size are identified. These wastes, or negative products, generate a large environmental burdens owing to useless overstock and idle processing.

1.2 Literature Review

A reasonable production lot-size determination is crucial for production management. The study of production lot-size determination has thus received a great deal of attention from researchers recently. Azaron et al. (2009) developed a stochastic dynamic optimal programming algorithm for obtaining dynamic economic lot-size. Nirmal and Tapan (2006) used multi-objective geometric programming to develop a multi-item finite production lot-size model. Kämpf and Köchel (2006) used simulation optimization with a genetic algorithm as an optimizer to identify the optimal production lot-size. However, these studies mainly focused on obtaining an optimal algorithm for determining production lot-size, seldom considering the aspects of environmental performance.

Additionally, as illustrated in section 1.1, environment-oriented research for production activities is a new trend. Many scholars have recently studied problems of environmental effectiveness in production systems. Ahmed (2011) presented a new green manufacturing system model to rebuild more eco-efficient manufacturing. Jon et al. (2011) presented a costing environmental simulation to provide a deeper understanding of environmental impacts in the manufacturing processes. Melnyk et al. (2001) integrated environmental concerns into the material planning activities and identified the waste streams generated in both quantitative and financial terms. Tang and Takakuwa (2011, 2012) used a simulation-based MFCA analysis method to reduce negative environmental impacts. However, these studies mainly focused on environment-oriented structures or concepts to analyze production activities and environmental impact. They seldom attached importance to the analysis of determination activities for production lot-size, which can cause environmental burdens.

Consequently, in this paper, the new environmental management accounting method called MFCA is applied to analyze the invisible wastes and environmental burden caused by inapposite production lot-size. Additionally, a regular correlation and change between the production lot-size and negative environmental impact are illustrated.

1.3 Research Phases

After the introduction, in section 2, the core contents and concept structure of the MFCA approach are reviewed. In section 3, a case study of a multi-variety and small-batch production system is described. Based on a Pull production mode and inventory decision-making mechanism, a corresponding back scheduling process for system operation is analyzed by building an original simulation model called the AS-IS model. Using the simulation results, the current production states and problems caused by inapposite production lot-size are presented. In section 4, a new simulation model using the concept of MFCA is constructed, called the AS-IS-NC model. By comparing the two simulation models, the corresponding negative environmental burdens hidden in the production processes are shown. After running several different simulation scenarios and sensitivity analyses, an impact mechanism for the negative environmental costs caused by production lot-size changes is explained.

2 MFCA APPROACH REVIEW

MFCA is an environmental management accounting method that focuses on tracing waste, emissions and non-products and on helping to boost an organization's economic and environmental performance. It is a system to measure the flow and stock of materials in the production process (raw materials and energy) in terms of physical and monetary units (Kokubu 2008). The original concept of MFCA was developed in Germany in the late 1990s as an environmental protection accounting technique. Since around 2000, it has been adopted widely in Japan and modified for increased ease of use by dividing materials into raw materials and energy sources, as well as measuring them by processes for easier improvement plans. To standardize MFCA practices, a working group (WG) 8 of ISO technical committee ISO/TC 207 (Environmental management) is currently working on the development of ISO 14051, Environmental Management-MFCA-General Framework, targeted for publication early in 2011 (Kokubu, Tachikawa and Takakuwa 2012).

MFCA has become recognized as a valuable management tool, balancing environmental and economic factors by reducing substantial waste costs. Figure 1 shows the concept of MFCA. It is also a management information system that traces all input materials flowing through production processes and measures output in finished products and waste. In MFCA, finished products and waste are respectively termed positive and negative products. In a processing-type production system, waste is generated in various steps of the production process. In particular, in the process of stocking and production, waste is substantially produced because materials and intermediate products that are overstocked as inventory may deteriorate in quality or be scrapped. Additionally, while materials or intermediate products are processed, residues or shavings may be generated. All of the wastes mentioned above are called "negative products" and lead to environmental burden. In MFCA, the idle processing, unnecessary energy and auxiliary material consumption caused during the waste generation are also called "negative products" and treated as environmental costs.

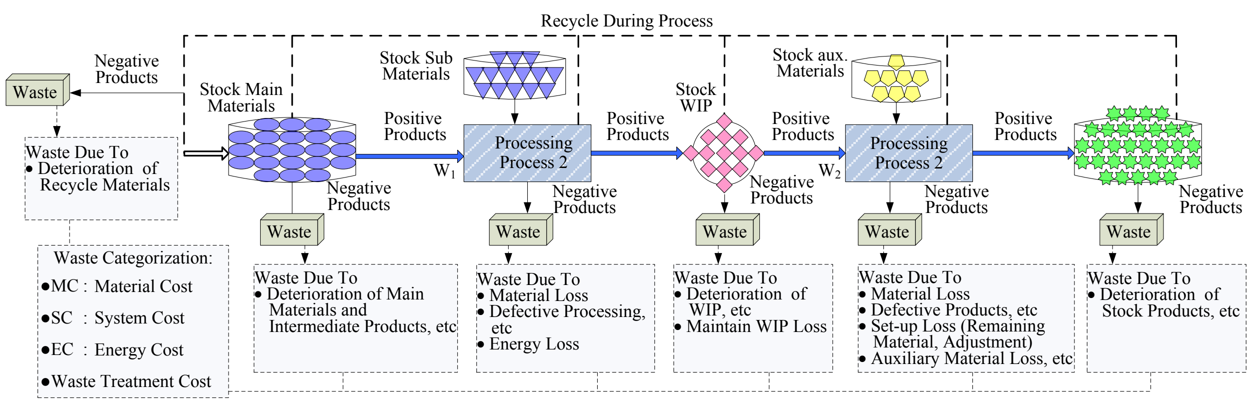


Figure 1: The concept of MFCA (Environmental Industries Office 2007).

The costs of both positive products and negative products are categorized into the following 4 groups (Environmental Industries Office 2010):

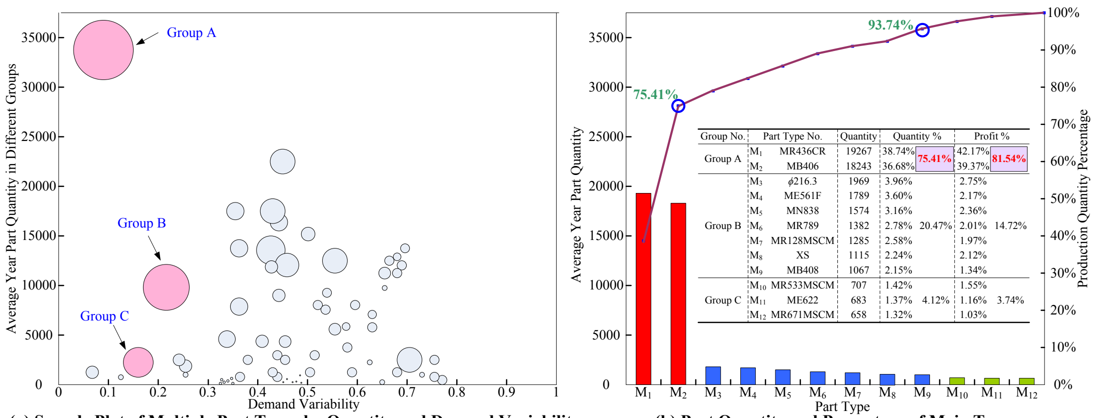
- MC: Material Costs (costs of materials including main materials for the initial process, sub materials added during midstream processes, and auxiliary materials such as detergents, solvents and catalysts);
- SC: System Costs (processing costs including labor, e.g., depreciation, overhead costs);
- EC: Energy Costs (electricity, fuel, utility and other energy costs);
- Waste Treatment Costs.

Many studies and practical applications have shown that by introducing MFCA, both economic and environmental performances are improved. However, cases of MFCA implementation and analysis for production lot-size determination in a multi-variety and small-batch production system are still scarce.

3 CASE STUDY

3.1 Case Description

This paper considers a case of a certain multi-variety and small-batch production system, which is located in a precision component manufacturing workshop of a Japanese company. To satisfy diverse demands from different customers, hundreds of part types are produced, and corresponding production lines are designed. As Figure 2 (a) shows, the part types are divided into tens of groups owing to changes in the market needs. Parts in groups A, B and C have large production quantity and lower demand variability compared to other groups. The economic benefit and productivity of these part types is crucial to the entire system. Figure 2 (b) shows that parts in group A occupy over 75% of production and 80% of profits. Consequently, in this paper, part types M_1 (MR436CR) and M_2 (MB406), composing group A, are selected as the research object. The study of the environmental problems for these part types will also provide some suggestions for the other part types.



(a) Sample Plot of Multiple Part Types by Quantity and Demand Variability **(b) Part Quantity and Percentage of Main Types**

Figure 2: Some relative statistical data on multiple part types from the current production.

Figure 3 shows the current production line logical structure for part types M_1 and M_2, which mainly comprises seven workstations sharing the same production line. To adapt to the requirements of part type diversification and rapid responses to market needs, different small production lot-sizes for M_1 and M_2 are adopted for each workstation, denoted as M_x-PL_y. In the Heat-Treatment Station and Shot-Blasting Station, processing begins only when a number of parts equal to the preestablished production lot-size have all arrived. For the other stations, however, the parts are processed one by one.

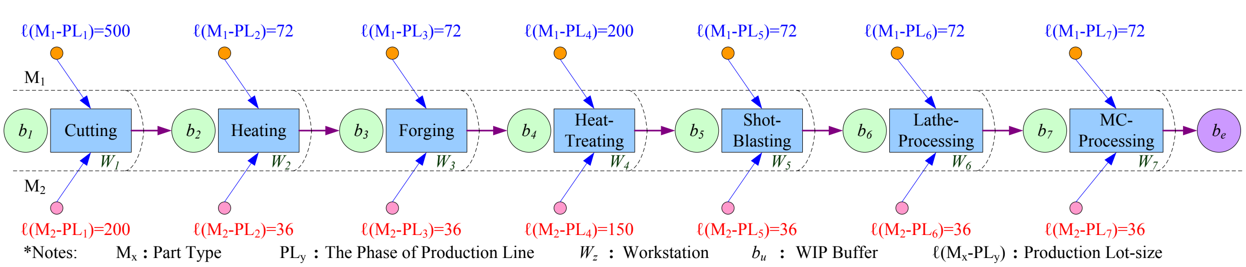


Figure 3: Production line logical structure for part types M_1 and M_2.

This production system is operated in Pull mode based on an inventory level decision-making mechanism. For one part type, when the order is arriving, the managers will first check the finished product inventory ($\boldsymbol{b_e}$) to determine whether the stock is large enough to provide the quantity ordered. If the order can be fulfilled, a corresponding quantity of parts will be delivered to the customer. If the order cannot be filled, the upstream Work-In-Process (WIP) inventory ($\boldsymbol{b_7}$) of the last workstation ($\boldsymbol{W_7}$) will be checked. In addition, for the last workstation $\boldsymbol{W_7}$, a certain quantity of intermediate products of multiple production lot-sizes from b_7 will be processed to meet the shortage of b_e. This approach is called a back scheduling for the production system operation. All of the checking work and production will thus be stopped until a certain upstream WIP inventory level ($\boldsymbol{b_i}$) of a certain workstation ($\boldsymbol{W_i}$) can fulfill the shortage of a certain downstream WIP inventory level ($\boldsymbol{b_j}$) for workstation ($\boldsymbol{W_j}$) production. Moreover, safety stock $\boldsymbol{s}$ is considered, and each WIP inventory level should be larger than $\boldsymbol{s}$ after determining the production quantity for the downstream workstation. Considering the design requirements of the production line and setup-time reduction, the production quantity for each workstation is multiple production lot-sizes. Figure 4 shows the logic for this Pull production mode.

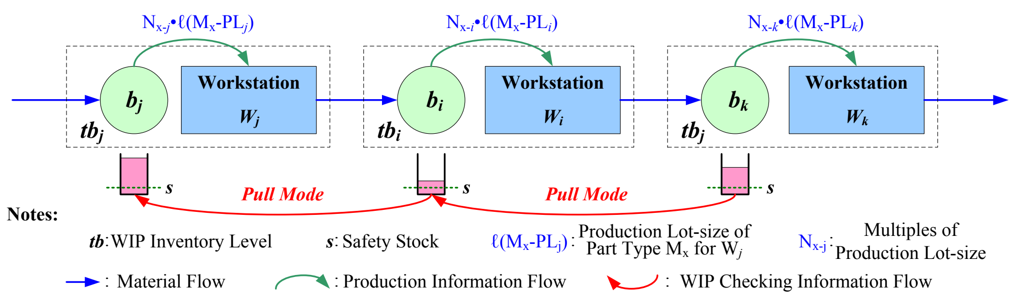


Figure 4: The logic of the Pull production mode based on an inventory level rule.

3.2 Original Simulation Model (AS-IS Model)

3.2.1 Simulation Model Construction

Based on the characteristics and structure of the real production system, an original simulation model is constructed to analyze the current production problems, called the AS-IS model. By running the simulation, the Pull mode and the determination process of the production lot-size for each part type in different workstations can be clearly understood. Furthermore, this AS-IS model facilitates introducing MFCA to the production system to identify hidden environmental problems effectively over a long running time. This study uses the Arena simulation platform to develop this AS-IS model comprising four parts, shown in Figure 5.

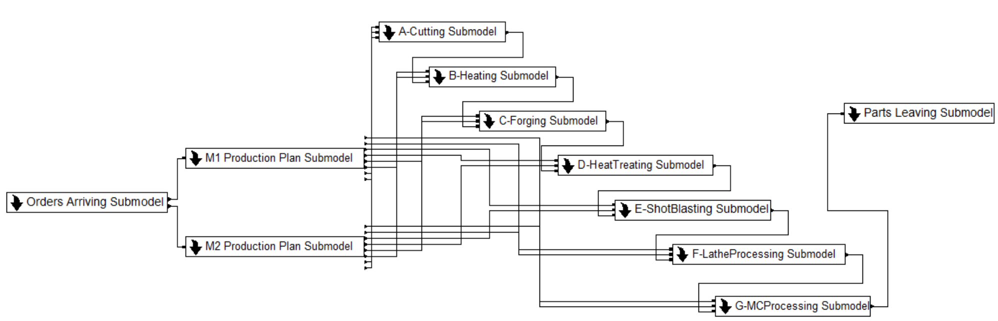


Figure 5: AS-IS simulation model.

Figure 6 shows the main simulation logic for the AS-IS Model. The first part is the Order Arriving submodel, designed to simulate the arrive of orders, and randomly create the production quantities needed by each order. The second part is the M_1/M_2 Production Plan submodel, designed to create a production plan and production lot-size determination for each workstation according to the Pull mode, based on an inventory level decision-making rule. The third part includes seven processing submodels, designed to implement the production plan on the corresponding workstations. The last part is the Parts Leaving submodel, which is used to develop the necessary statistics to analyze production system performance.

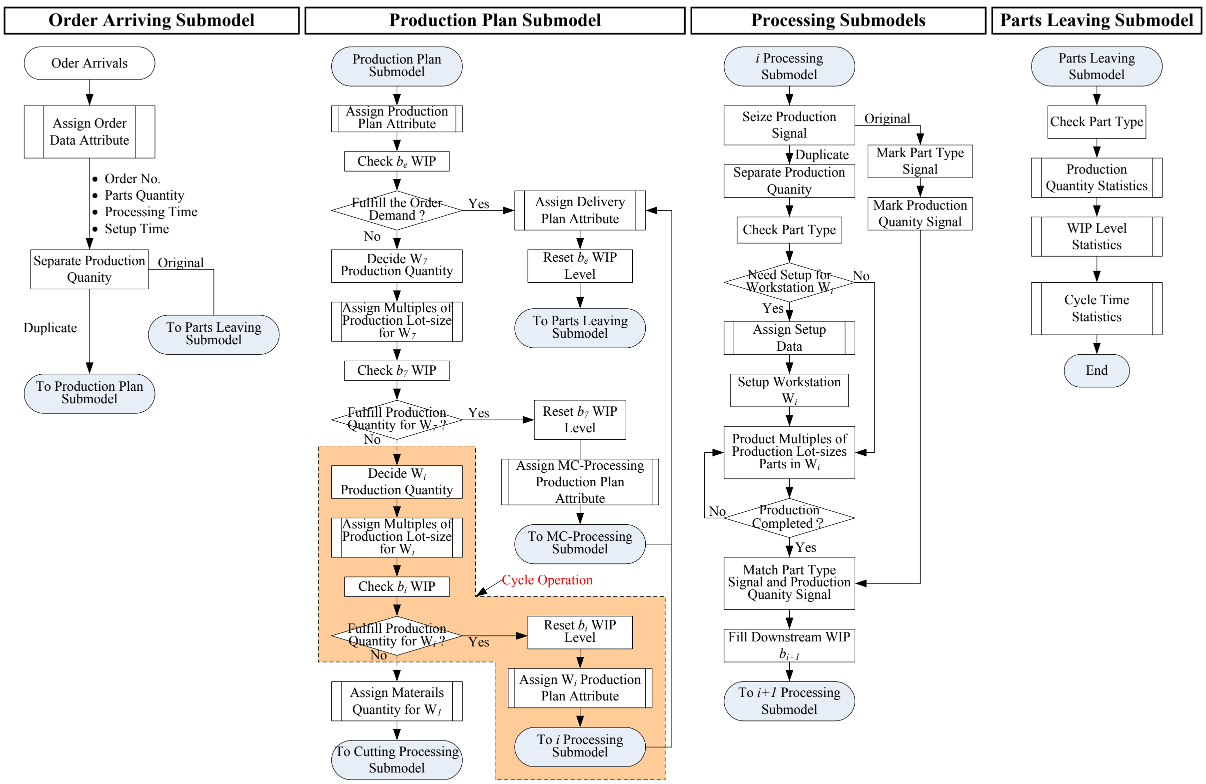


Figure 6: The main simulation logic of the AS-IS model based on back scheduling.

Statistical analysis data from the latest year of real production is used as input parameters. To run the simulation, a steady-state simulation is appropriate. The warm-up period is selected as 5000 minutes, 20 replications are performed, and a common random number method is applied. To ensure simulation randomness similar to the real system, the random distribution data and main parameters are set in the AS-IS model, shown in Table 1.

Table 1: Main simulation data and parameters.

Parts Processing Time *Unit/Min*		M_1	M_2	Defective Products Rate M_1	Defective Products Rate M_2	Processing Waste Rate M_1	Processing Waste Rate M_2	Safety Stock *s* M_1	Safety Stock *s* M_2
A	Cutting	TRIA(0.03,0.04,0.05)	TRIA(0.60,0.66,0.70)	0	0	0.059	0.055	150	50
B	Heating	TRIA(0.50,0.55,0.58)	TRIA(0.75,0.80,0.83)	0	0	0	0	20	10
C	Forging	TRIA(0.23,0.25,0.28)	TRIA(0.63,0.71,0.75)	0	0	0.091	0.071	20	10
D	Heat-Treating	1440	1440	0	0	0	0	50	30
E	Shot-Blasting	TRIA(7.5,8.01,8.43)	TRIA(9.50,10.12,10.76)	0	0	0.0002	0.0002	20	10
F	Lathe-Processing	TRIA(0.92,1.05,1.67)	TRIA(5.87,6.33,7.01)	0.03	0.03	0.174	0.149	20	10
G	MC-Processing	TRIA(2.25,2.92,3.41)	TRIA(15.12,17.06,19.63)	0.05	0.05	0.118	0.221	20	10

Part Order Data	Order Arriving Interval *Unit/Min*	Part Quantity *Unit/Quantity*	Part Weight *Unit/kg*
M_1	UNIF(2880,4320)	DISC(0.33,144,0.67,180,1,216)	11.37
M_2	UNIF(1440,2880)	DISC(0.3,36,0.7,60,1,108)	22.81

3.2.2 Simulation Validation

After the simulation model has been generated, validation of the model is necessary. The correlative validation data were compared to the existing data statistics from the real system, shown in Table 2. As shown in Table 2, each data point from the AS-IS model is close to that of the real system. All of the difference ratios are below 10%. Additionally, when extreme cases are tested by fixing the processing time, the order arrival interval and the quantity of parts in one order, the inventory level for each WIP buffer presents a regular cyclical change, and each average value is almost constant. This tentative hypothesis is consistent with the peculiarity of the Pull mode. Consequently, all of these tests are validated, confirming that the AS-IS simulation model behaves in the same manner as the real system.

Table 2: Validation data comparing the AS-IS model with the real system (the latest 3 months of data).

Workstations		AS-IS Model (Simulation System)				Existing Data Statisitic (Real System)				Difference Ratio			
		Effective Processing Time *Unit/Hours*		Output *Unit/Quanity*		Effective Processing Time *Unit/Hours*		Output *Unit/Quanity*		Effective Processing Time *Unit/%*		Output *Unit/%*	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
A	Cutting	507	451	4214	4045	553	477	4620	4423	8.32	5.45	8.79	8.55
B	Heating	513	441	4113	4126	542	482	4515	4327	5.35	8.92	8.90	4.65
C	Forging	531	433	4305	4174	573	476	4734	4485	7.33	9.03	9.06	6.93
D	Heat-Treating	487	397	4016	3711	519	431	4363	3972	6.17	6.03	7.95	6.57
E	Shot-Blasting	515	423	4257	4118	569	456	4698	4475	9.03	7.24	9.39	7.98
F	Lathe-Processing	527	440	4249	4195	554	473	4579	4413	4.87	6.98	7.21	4.94
G	MC-Processing	504	435	4178	4065	538	465	4451	4356	6.32	6.45	6.13	6.68

3.2.3 Simulation Results from the AS-IS Model

The WIP inventory levels for each workstation, based on running the AS-IS simulation model, are shown in Figure 7. Because of the higher production lot-size for M_1, the WIP inventory value is larger than for M_2. Based on the same reason above for the Cutting and Heat-Treating workstations compared with the others, the inventory values of their downstream WIP b_1 and b_5 are also larger. Additionally, each WIP average value is much larger than the respective safety stock. To meet demand rapidly, increasing production lot-size can satisfy downstream workstation production in time, but will cause overstocks. Additional stocks also generate substantial scrap and waste to burden the environment.

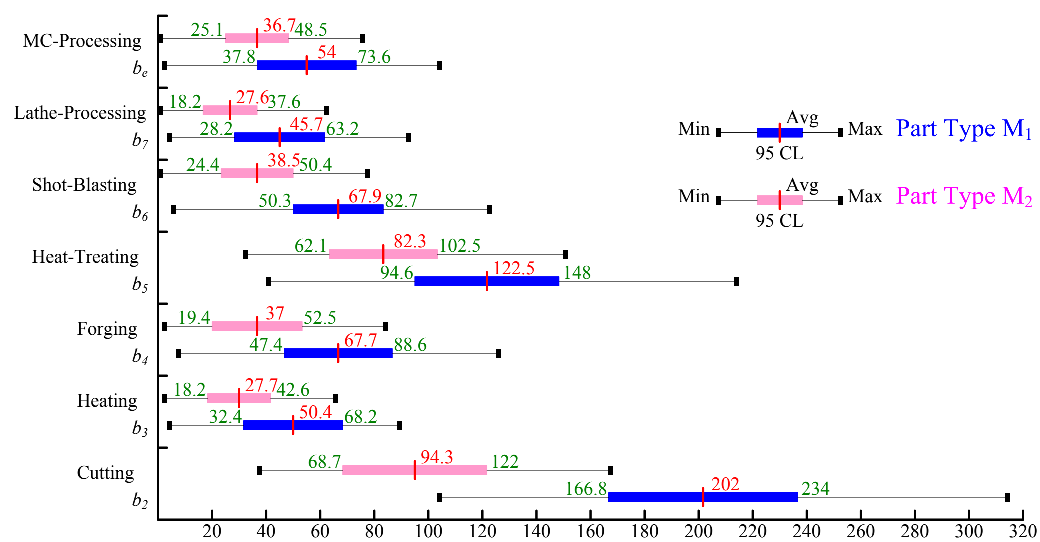


Figure 7: WIP inventory level of simulation results from the AS-IS model.

From the data in Table 3, the average value of each WIP inventory time exceeds 3 days (4320 minutes). A longer inventory time leads to a higher scrap probability of overdue overstocks and more defective intermediate products or materials. Huge amounts of scrapped waste, residues and shavings cause both financial profits and environmental burden.

Table 3: Simulation results of the AS-IS model.

			WIP Inventory Time Distribution Normal Distribution $X \sim N(\mu, \sigma^2)$ (*Unit/Min*)				Scrap Probability of Overstock (*Unit/%*)		Scrap Probability of Defective Products in WIP		Processing Residues or Shavings Probability		Frequency of Setup Time	
			M_1		M_2		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
			μ	σ^2	μ	σ^2	>10080 *Mins*	>14400 *Mins*	(*Unit/%*)	(*Unit/%*)	(*Unit/ % /kg*)	(*Unit/ % /kg*)	(*Unit/ %*)	(*Unit/ %*)
A	Cutting	b_2	6087	2753	7729	4396	7.35	6.46	0.75	0.53	0.037	0.024	13.13	12.04
B	Heating	b_3	5723	2658	7536	4014	5.06	4.36	0.84	0.67	0	0	27.65	25.13
C	Forging	b_4	5269	2447	7230	3731	2.46	2.73	0.32	0.19	0.072	0.065	28.96	30.74
D	Heat-Treating	b_5	6804	3094	8452	5757	14.48	15.08	1.46	1.15	0	0	14.67	11.56
E	Shot-Blasting	b_6	5070	2985	6784	4415	4.66	4.23	0.91	0.78	0.0002	0.0002	31.46	37.28
F	Lathe-Processing	b_7	4865	2831	6152	4278	3.27	2.69	2.27	1.88	0.141	0.128	37.51	35.97
G	MC-Processing	b_e	4591	2712	5720	σ^2	2.15	1.05	2.89	2.50	0.105	0.193	32.73	38.85

Facing the production lot-size in this case study, overstocks, scraps and wastes are obviously created, but their costs are usually ignored in conventional cost accounting. Hidden environmental problems during the production process are not realized clearly. Consequently, the concept of MFCA should be used to reconstruct the model and to visualize the hidden wastes impacting the environment by automatically identifying positive products and negative products. Moreover, based on MFCA technology, the impact of the regulation of production lot-size on the negative environmental costs needs to be analyzed.

4 SIMULATION ANALYSIS FOR THE AS-IS-NC MODEL INTRODUCING MFCA

4.1 Construction of the AS-IS-NC Model Using the Concept of MFCA

To apply the concept of MFCA, the actual wastes generated during the production process need to be further understood. Because of the current unreasonable production lot-size, huge overstocks are produced, and an excess of energy, auxiliary fluids and operations are wasted. According to the requirements from the production design and the customers, overstocks lead to useless stock, idle processing and environmental maintenance wastes. Moreover, overstocks cause large amounts of scraps from overdue and defective intermediate products or materials. All of these wastes and scraps produce a substantial environment cost and burden.

In this paper, the AS-IS model is reconstructed to introduce the concept of MFCA by embedding a Monitor submodel, which is called the AS-IS-NC Model. All of the production operations are monitored, and all of the material flows are traced by the Monitor submodel. They are also divided into positive products and negative products, and the costs are calculated, as shown in Table 4.

Table 4: Cost categorizations based on MFCA.

	Positive Products Cost	Negative Products Cost
MC	● Material Cost ● Auxiliary Fluids Cost	● Material Waste Cost ● Material Scraps Cost ● Auxiliary Fluids Waste Cost ● Environment Maintenance Cost
SC	● Processing Cost ● Labour Cost ● Management Cost ● Workstation Setup/Reset Cost	● Idle Processing Waste Cost ● Idle Labour Waste Cost ● Idle Management Waste Cost ● Idle Workstation Setup/Reset Waste Cost ● Inventory Maintenance Cost
EC	● Energy Cost	● Energy Waste Cost

4.2 Simulation Results from the AS-IS-NC Model Using the Concept of MFCA

The results of running the AS-IS-NC simulation model are compared with the results of the AS-IS model in Table 5. It can be observed that using MFCA can uncover invisible costs in the production processes; in particular, the negative products cost referring to environmental impacts become visible. For each unit part in the AS-IS-NC model, the negative products cost of M_1 makes up 36.65% of the total cost, and the negative products cost of M_2 makes up 30.64% of the total cost. By simulation tracing and analysis, the source of these negative products cost is found to be the inapposite production-lot size. Because the negative products cost is invalid for this production case, these high percentages mean that the determination strategy for the production lot-size needs to be analyzed and improved to reduce the environmental burden.

Table 5: Cost results of unit part comparing the AS-IS-NC model and the AS-IS model.

(*Unit*/JPY ￥)

AS-IS-NC Simulation Model						AS-IS Simulation Model				
MFCA		M_1		M_2		Conventional Cost Accounting	M_1		M_2	
		Avg(1)	*SD*(2)	*Avg*	*SD*		*Avg*	*SD*	*Avg*	*SD*
Positive Products Cost	MC	1129.61	14.45	2240.19	31.71	Materials Cost	2009.77	14.45	3658.36	31.71
	SC	1251.24	18.50	2717.67	39.95					
	EC	152.77	2.22	411.87	4.82					
	TPC(3)	2533.62	32.17	5369.73	49.55					
Negative Products Cost	MC	78.16	11.76	1318.17	20.90	Process Cost	1989.43	20.93	4083.71	43.28
	SC	669.23	17.00	971.21	27.76					
	EC	16.19	0.07	82.96	0.41					
	TNC(4)	1465.58	20.69	2372.34	25.78					
Total Cost		3999.2	41.88	7742.07	59.14	Total Cost	3999.2	27.66	7742.07	68.47
TNC-P(5)		36.65%		30.64%						

Notes: (1): *Avg = Average Value* (2): *SD = Standard Deviation* (3): TPC = Total Positive Products Cost (4): TPC = Total Negative Products Cost
(5): TNC-P = Negative Products Cost / Total Cost

4.3 Sensitivity Analysis for Production Lot-size Determination

In this paper, a sensitivity analysis is used to analyze the changes in the negative products cost as a result of regulating the production lot-size. Additionally, in this case study, the production lot-size for the Cutting and Heat-Treating stations is set as a fixed value due to the current production schedule and technological design. The production lot-size for the other stations can be regulated by running several different simulation scenarios. To reduce the reciprocal effects, the production lot-size of M_1 and M_2 in each workstation is regulated to the same value.

From Figure 8, it can be observed that the negative products cost of a unit part is changed. With increasing production lot-size, four similar curve sections for each part type are obtained. Therefore, the negative products cost for each section is changed in almost the same manner. The cycle value of the production lot-size is approximately 60, and each cycle range in the Figure 8 is the same for both part types. This situation disobeys the mass production mode that increasing the production lot-size can generally reduce costs. First, corresponding to the parts quantity distribution for the current order demand of each part type, there exists a relative appropriate production lot-size radix with the lowest negative products cost. Second, based on this radix, multiple production lot-sizes produce the appropriate value with similar lowest negative products cost; Third, through simulation monitoring and tracing, corresponding to each production lot-size point in each cycle changing region, the overstocks left in the inventory and the useless idle processing are similar; Four, inapposite production lot-size generates substantial scraps and wastes, increasing the negative products and environmental costs that are invisible during the production process and are easily ignored by the conventional cost accounting method.

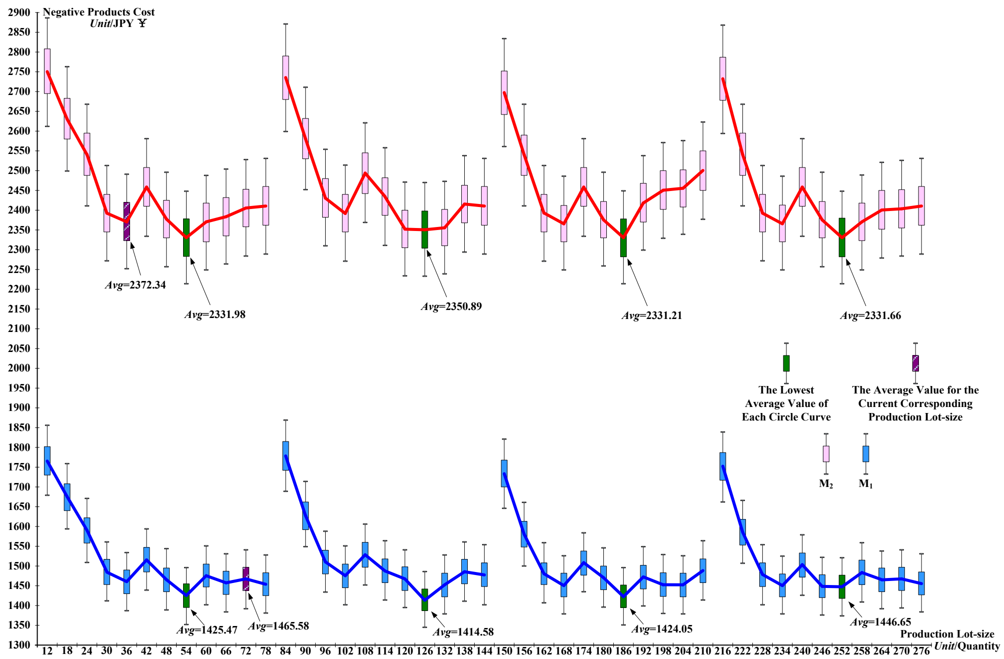


Figure 8: Negative products cost of a unit part by regulating production lot-size.

From Figure 9, for the total cost, the negative products cost percentage of the unit part is also changed in a cyclical manner with changing production lot-size. The cycle value is similar to the one found in Figure 8 at approximately 60. However, in contrast to Figure 8, the lowest points of the production lot-sizes and cycle range of M_1 are not the same as for M_2. Moreover, comparing these two figures, the production lot-size value corresponding to the lowest point is not coincident. This result means that for a unit part, regulating the production lot-sizes to obtain the lowest negative products cost percentage may not produce the lowest negative products cost overall.

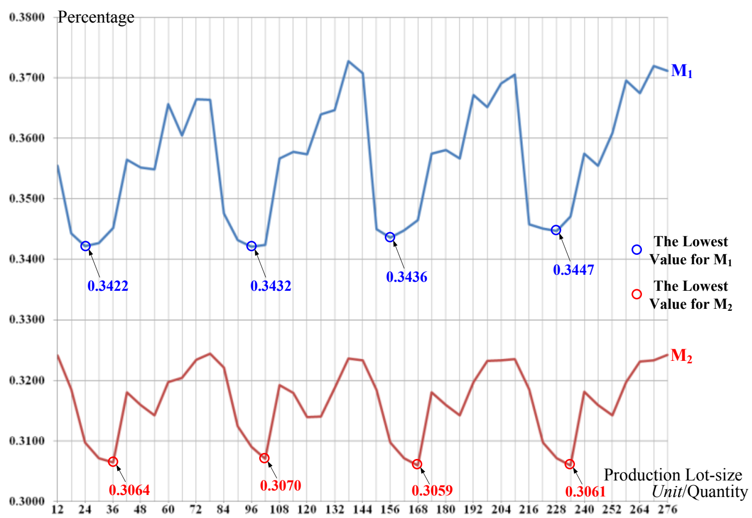


Figure 9: Negative products cost percentage of a unit part by regulating production lot-size.

These two figures indicate that the determination strategy for the production lot-size has significant impacts on the negative products cost and environmental burden. Additionally, these impacts present a regular change. It is not demonstrated that blindly increasing or reducing the production lot-size can improve the economic profits and environmental performance. Therefore, such analysis can motivate managers to find the hidden negative products costs and regular change to identify an appropriate production lot-size, then enhance material productivity and significantly reduce the negative environmental impacts.

5 CONCLUSIONS

In this paper, an AS-IS model is constructed to simulate the Pull production mode and back scheduling for a case study of a multi-variety and small-batch production system. By analyzing the simulation data from running the AS-IS model, substantial overstocks and idle processing are traced in the production system owing to the current unreasonable production lot-size determination. Moreover, overdue overstocks and defective intermediate products or materials are scrapped in abundance, causing a huge environmental burden that is ignored in conventional cost accounting. However, the effectiveness of a new environmental accounting method called MFCA is confirmed through the construction of an AS-IS-NC simulation model introducing the MFCA concepts. Based on MFCA, the abandonment of the dead stocks, useless materials and idle processing are reflected as the generation of negative products cost in terms of monetary units, which are invisible during production. Additionally, as analyzed in section 4.1 and 4.2, after comparing the AS-IS-NC model and the AS-IS model, huge negative products cost and environmental cost caused by the current production lot-size determination policy are identified. Moreover, through running several different simulation scenarios, two sensitivity analyses are obtained to analyze the changes in the negative products cost as a result of regulating the production lot-size. After observing the characteristics of similar cycle curves with gradually regulating the production lot-size, two regular changes in negative products cost and the corresponding percentages for the unit part are presented. These change trends provide production managers with effective and strategic knowledge or instructions for determining appropriate production lot-size and for considering both economic and environmental benefits.

ACKNOWLEDGMENTS

The authors wish to express their sincere gratitude to Mr. Y. Watanabe of Metal Worker Toa & Arai Company, Ltd. and Mr. Y. Murata of Fujita Health University, for their cooperation in completing this research. This research was supported by the Grant-in-Aid of the Japan Society for the Promotion of Science (JSPS).

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