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HYBRID ADVANCED SCEDULING OF LABEL PACKAGING PRINTING PROCESS ADVANCEMENT FOR LETTERPRESS PRESS SYSTEMS

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Abstract:
Printing process improvement has recently transformed into an impacting bottleneck after digitalization throughout the printing press Despite the recent success of consistency and results of quality at the pre-press, press, and post-press machines, timely delivery and lead time consistency are the biggest obstacles for all printers in Thailand New hybrid scheduling algorithms are innovated from this paper in the needs of guaranteed lead time and cost efficiency Two of the six existing press systems consisting letterpress flatbed and letterpress intermediate rotary press systems are being studied, simulated, and experimented These roll to roll types of raw material printers found to have distinct maximum speed ranging from 10 to 60 meters per minute or 40 to 200 rounds per minute As observed results, it is shown that the advanced hybrid scheduling enhanced more than 30 percent of the flexibility to cope with rush orders and job shifts, and reduced no less than 20 percent of job delay frequency Besides these significant results, the new algorithm requires planner and the printer operator communicated with printing algorithms to perform with relatively fewer human errors These indicators are the introductory and promising results from the new hybrid scheduling algorithm To conclude, the hybrid multilevel scheduling is a comprising digital advancement in planning process for press manufacturers to implement and further expand its application fields

Keywords Hybrid Multilevel Scheduling Algorithm, Label Printing Scheduling, Printing Press Innovation and Digitalization, Innovated Scheduling Advancement, Communication Assurance Priority, Letterpress Press Scheduling, Intermediate Rotary and Flatbed Press

1. OBJECTIVE

There are numerous objectives that this research aims to accomplished. Typically, it aims to pinpoint significant factors impacting the performance of press and inspection processes. Then to purpose an effective scheduling algorithm that fits roll to roll printing with the production and post inspection processes. Other than that, it should enhance the flexibility to adapt to the amount of rush orders and order shifts at a minimum of 20 percent frequency. It should also improve no less than 10 percent with amount of job orders delays externally to clients. Performing better financial figures in cost savings than that of conventional scheduling algorithms is also a target. Then the results, eventually, should show a reduction of at least 50 percent of the human errors made in communication and planning of scheduling.

2. SCOPE

The technical field and system types of the packaging printers varies distinctively from systems, applications, to products. This research, eventually, emphasize on the roll and sheets label printing markets in Thailand with polymer plate press printers. The raw material used in printing are mainly roll forms of paper and film synthetic types. The printing press process scopes down to only flatbed, intermediate rotary, and full rotary type of press machines. The initial phase of the results enhances on the in-press and post-press scheduling algorithms.

3. INTRODUCTION

The increased wage with constant productivity has turned the conventional printing press industry to shift to the digital evolution Similar to those of developed high wage countries, Thailand's pay to productivity index has fallen from the rank of 27th back in the 2012 to 53th in 2014 compared among 144 countries Forum, 2012-2014 Inquiring more labor cost while facing the limitation of labor outputs are now the obstacles of most printing manufacturers Hence, the trend to apply digitalization is a definite trend to cope with the limitation of labor cost and labor productivity Organizational innovation of technology implementation is both core competency and competitive strategy for printing manufacturers Kearns, Hull, & Taylor, 2005 The evolution of pre-press digital workflow based on PDF has dominated the printing industry with standards to set quality, consistency, and uniformity Romano, 2004 Its combination with the pre-press digital integrated plating machine, the CTP (Computer to Plate), made from RR Donnelly, Creo, Adobe, Aldus, and Apple Computer result the extraordinary impact on the printing firms Adams II & Romano, 1996 In fact, Szentgyorgyvolgvi claims that 79 percent among the 72 printing users has agreed with less plating time consumed and 84 2 percent of them proves that the CTP plate enhance the printing quality Szentgyorgyvolgyi R , 2008

Besides the success of digital implementation to the pre-press process, the press process has also revolutionized since the invention of conventional moving printers of J Gutternberg to the robust offset and digital printing press The post-process even developed to the level of auto-inspection with Lab coloring quality standard and technology These typical digital inventions introduce the pressing process to its next phase of consistency, quality, efficiency, and applications The end user, nonetheless, favors further to that of lead time perspective Timely delivery with no order shortage is one of the top necessity for printed packages towards achieving higher customer satisfaction since printers are the unknown OEM Original Equipment Manufacturer Job shifts before completion resulting from station down and rush orders would duplicate the fixed set up costs In fact, Rush orders draws the time efficiency and paper waste meters worsen in terms of set up cost for both printing and laminating stations of printers Moix, 2013 Working overtime or night shift would also have a roughly 6 percent negative impact on productivity and revenue while enhancing shifts likelihood from the enhanced wage field experiment Fehr & Gotte, 2004 With the unsolved time management for printing manufacturers and the recent success of digitalization in plating and machinery of printers, digitalization on the scheduling throughout the pressing processes comes the catastrophe Unfortunately, the common material planning scheduling widely used with pushing strategy are inapplicable Printing press manufactures require more advanced scheduling algorithms due to the fact that printers use pull strategy while seeking a relatively short lead time within few days of due

4. METHODOLOGY AND SAMPLING

4.1. Materials

Printing Press Stations

We have conducted the innovated scheduling algorithm on the two packaging related printing systems with the polymer plates The three existing printing press machines using such plate such as flatbed, intermediate and full rotary are also included in the studies The detailed specifications of the types and process time of each press printers are listed in table 1 The speed is described in two methods as of meters per minute mpm and rounds per minute rpm These machines each have their own unique strength that favors distinct customer segments

Table Printing press machine stations used in scheduling

List	Machine Type	Symbol	Press Type	Plate Type	Speed Mpm	Speed rpm
5 1 1 1	Letterpress Flatbed	PFB	Letterpress	Polymer	9	60
5 1 1 2	Intermediate Rotary	PIR	Letterpress	Polymer	15	100
5 1 1 3	Full Rotary	PFR	Flexography	Polymer	60	400

Source In-depth Interview with the printers

Pre-Press Stations

These press printers will chronologically shift its printed packages to the post-press process of value adding process and inspection process Most printing products requires die-cutting and inspection for the applications of the end users The simulation and trial of the hybrid advanced scheduling is used with both paper and film forms of the raw materials from roll to roll type The type of the raw material required and the speed of these post-press inspection machines are stated within table

Table Post-press machine stations used in scheduling

List	Machine Type	Symbol	Raw Material Type	Speed mpm	Speed rpm
5 1 2 1	Die Cut Pump Machine	DF	Roll to Roll or Roll to Sheet	15	100
5 1 2 2	Slitter Machine	SR	Roll to Roll	50	333
5 1 2 3	Roll Inspection Machine	QRI	Roll to Roll	15	100
5 1 2 4	Sheet Inspection Station	QSI	Sheet to Sheet	7 5	50
5 1 2 5	Auto Inspection Machine	QAI	Roll to Roll	50	333

Source In-depth Interview with the printers

4.2. Methodology

The well-known enterprise resource planning systems consisting material resource planning has been widely used in several industries With a short due date to delivery and many uncontrollable noises, nevertheless, the printing industry still lacks an effective scheduling system The hybrid multilevel scheduling algorithms are to be performed continuously with the form of the 7 days Gantt chart of optimal printing order sequence Cox et al Cox, Blackstone, & Spencer, 1992 claimed that Gantt chart is “the earliest and best known type of control chart especially designed to show graphically the relationship between planned performance and actual performance ”

Define the conventional process

- Analyze the workflow and scheduling process of current press and post-press process

- *Identify the needs for change*
- Pinpoint the drawbacks of conventional scheduling methodology and algorithm towards printing press
- *Analyze the improvement process*
- Collect the results of the hybrid advanced scheduling and compared its significance

4.3. Sampling Methods and Data Collection

ISO 9001 planning historical records

After demonstrating the machines used in the process phase of the scheduling algorithm, the type of orders flow in as data inputs is eventually essential The printing orders used to simulate the scheduling algorithm are 78 65 percent of the popular CMYK process included jobs and 21 35 percent of non-CMYK jobs requests Since the CMYK process color dots overlaps to create almost all of the illusions, our scheduling systems use it to best illustrates most types of printers

Table 3: Printer job order analysis categorized with color types

Year Month	Job Types Items\	Pure CMYK Process Color		CMYK with Special Color		Non-CMYK Process Color	
		Freq		Freq		Freq	
2015 1	Frequency	203	38 16	187	35 15	142	26 69
	Order Quantity	13,219,770	41 63	8,881,570	27 97	9,656,790	30 41
	Rounds	3,489,306	45 38	2,860,117	37 20	1,339,551	17 42
2015 2	Frequency	170	41 46	156	38 05	84	20 49
	Order Quantity	9,646,416	39 87	10,781,293	44 56	3,767,400	15 57
	Rounds	3,018,728	43 34	2,904,894	41 71	1,041,385	14 95
2015 3	Frequency	206	36 79	213	38 04	141	25 18
	Order Quantity	10,858,779	35 02	9,108,770	29 38	11,036,040	35 60
	Rounds	3,282,197	38 49	2,914,835	34 18	2,330,201	27 33
2015 4	Frequency	189	39 46	160	33 4	130	27 14
	Order Quantity	9,735,940	37 37	6,575,825	25 24	9,741,096	37 39
	Rounds	2,723,362	42 95	2,279,877	35 96	1,337,136	21 09
2015 5	Frequency	207	41 65	173	34 81	117	23 54
	Order Quantity	12,849,247	46 07	8,305,650	29 78	6,734,401	24 15
	Rounds	3,242,217	40 22	2,764,436	34 29	2,054,123	25 48
2015 6	Frequency	195	36 79	191	36 04	144	27 17
	Order Quantity	13,413,821	47 45	9,886,310	34 97	4,972,115	17 59
	Rounds	2,759,064	39 75	2,777,895	40 02	1,404,792	20 24
TTL	Frequency	1,170	38 90	1,080	35 90	758	25 20
	Order Quantity	69,723,973	41 22	53,539,418	31 65	45,907,842	27 14
	Rounds	18,514,874	41 58	16,502,054	37 06	9,507,188	21 35

Source Historical Records from ISO9001 documentation of printer of LLC

Direct observation on time consumed on the conventional scheduling progress

Despite the fact that printers have a relative short lead time ranges from 3 to 7 days before due, the printing press scheduling progress are examined into three steps of input queue sheet, update queue sheet, and prioritize the printing queue The conventional scheduling period is on a daily basis that could have taken the most up to date information into the scheduling considerations The CPU Core Processor Utilization scheduling experiment were taken at year 2015 from January to March whereas MTTD Minimum Time to Deadline scheduling were taken at trial during June to August. In fact, these 77 days trials have distinct normal planning time of 215 89 minutes for CPU scheduling and 247 07 minutes for MTTD scheduling respectively They also resulted with 0 53 and 1 18 errors per day

Table 4: 77 Days direct observation on minute of time consumed on the CPU scheduling

Priority Day\	Number of Processors	Input the production orders	Update the production queue sheet	Prioritized the queue of each level processors	Total Scheduling Time Consumed	Human errors
Sum	13	1,358 81	8,499 71	5,685 7	15,544 22	38
Percentage	n a	18 87	54 68	36 58	100	n a
Average	n a	18 87	118 05	78 97	215 89	0 53
Standard Deviation	n a	5 67	16 69	21 86	44 21	0 50

Source Direct observation with the LLC printer

Table 5: 77 Days direct observation on minute of time consumed on the MTTD scheduling

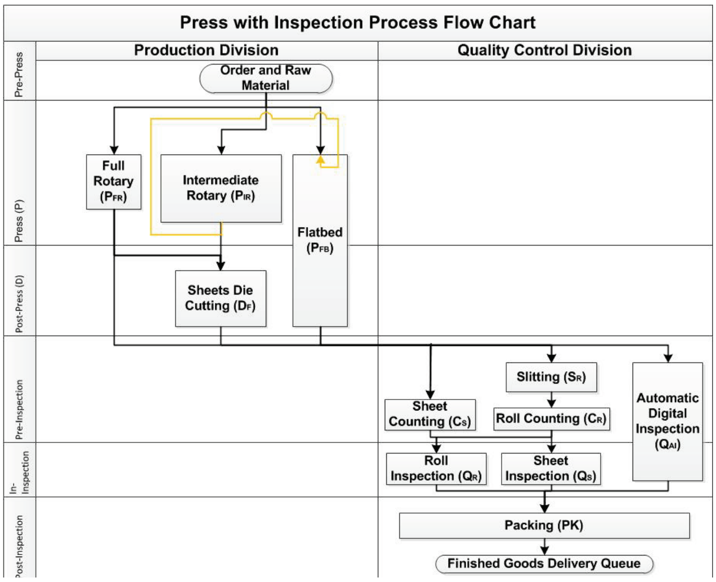
Priority Day\	Number of Processors	Input the production orders	Update the production queue sheet	Prioritized the queue of each level processors	Total Scheduling Time Consumed	Human errors
Sum	13	7,551 73	7,537 85	2,699 33	17,788 91	85
Percentage	n a	42 45	42 37	15 17	100	n a
Average	n a	104 89	104 69	37 49	247 07	1 18
Standard Deviation	n a	8 22	8 21	4 63	21 06	1 01

Source Direct observation with the LLC printer

In-depth interview of press and post-press processes

The process for all printers are similar to one another with having post-press activity on-line on the machine or off-line after the progress of printing stations as shown in picture Some repeating and large printing orders require printers to finish the job on-line within the press process to save time and cost while shorter orders are done with the combination of the post-press stations However, all the finished printing orders are to be inspected and packed before delivery Each process is abbreviated with its given symbol sign and shown with their distinctive set-up time and run time

Picture 1: The press and post-press process illustrated with flowchart of the LLC printer



Source In-depth Interview with the LLC printer

Documentary Information on rush orders, order shifts, human errors, production and inspection productivity slag, and order delays

These five indicators will be the key monitors of the results and impacts of a scheduling system A sustainable scheduling system should be able to cope with rush orders and order shifts while minimizing order delays The integrated systems would enhance printing press manufactures with better and more efficient service to customers Romano, 2004 The integration of systems throughout the press and post press process will enhance the flexibility to special and timely customer requests The current capabilities of flexibility results are to be shown throughout in table 6, table 7, and table 8 with the same experiment time period from the previous experiment of time consumption in scheduling.

Table 6: Symbols and factors of scheduling performance indicator evaluating scheduling algorithms

Symbol	X1	X2	X3	X4	X5	Y
Factor	Rush orders	Order shifts	Human error	Production productivity	Inspection productivity	Order delay

Table 7: Result of performance indicators of CPU scheduling algorithm

Year Month	2015 1		2015 2		2015 3		CPU TTL	
Job Types	Freq	QT	Freq	QT	Freq	QT	Freq	QT
X1	18	2,277,500	15	891,996	13	565,700	46	3,735,196
X2	6	1,290,000	8	1,088,300	6	548,500	20	2,926,800
X3	3	115,000	5	145,000	3	48,000	11	308,000
X4	1	100,000	5	278,696	20	1,563,590	26	1,942,286
X5	10	1,930,000	1	10,000	16	3,913,250	27	5,853,250
Y	27	4,745,000	20	2,576,996	58	7,904,540	105	15,226,536

Source Documentary records from printer of LLC printer

Table 8: Results of performance indicators of MTTD scheduling algorithm

Year Month	2015 6		2015 7		2015 8		CPU TTL	
Job Types	Freq	QT	Freq	QT	Freq	QT	Freq	QT
X1	9	2,277,500	11	781,980	19	745,600	13	2,395,580
X2	32	1,290,000	34	5,735,300	14	5,184,000	6	15,577,250
X3	1	30,000	1	500,000	1	500,000	3	530,000
X4	8	231,000	0	0	19	981,960	20	1,212,960
X5	3	350,000	4	1,020,000	1	149,100	16	1,519,100
Y	15	5,600,450	22	9,081,730	40	8,270,440	58	22,952,620

Source Documentary records from printer of LLC printer

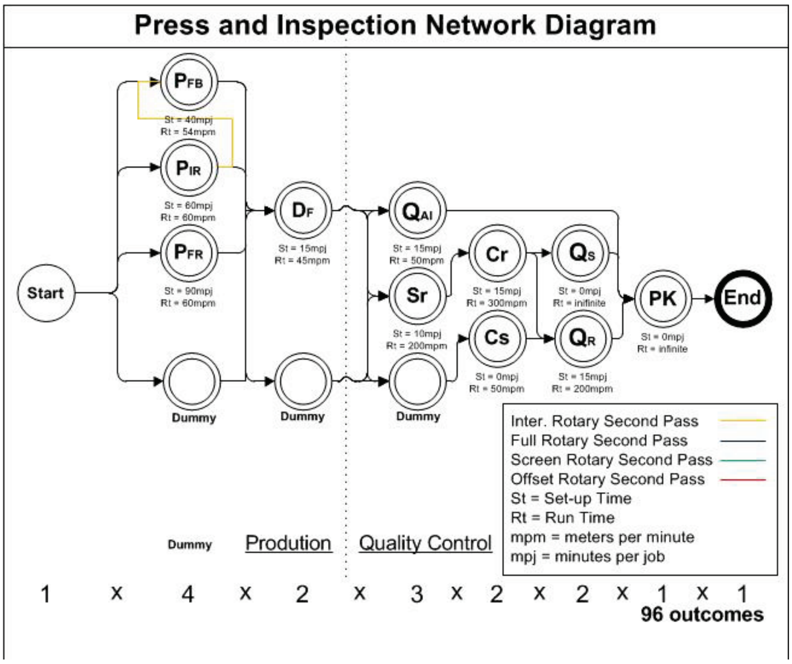
5. DATA ANALYSIS

5.1. Define the conventional process

Analyze the current press and post-press process

Previous research and work has support the overall role of scheduling by explaining scheduling problems are involving various network structures That is, the layout of machines, flow of materials, and process specification of the scheduling process Reklaitis, 1982 In picture 2, the run time and set-up time of each process is determined while illustrating the interrelationship of all the 11 processes with 96 possible outcomes

Picture 2: Conventional Press and Pre-Press Network Diagram



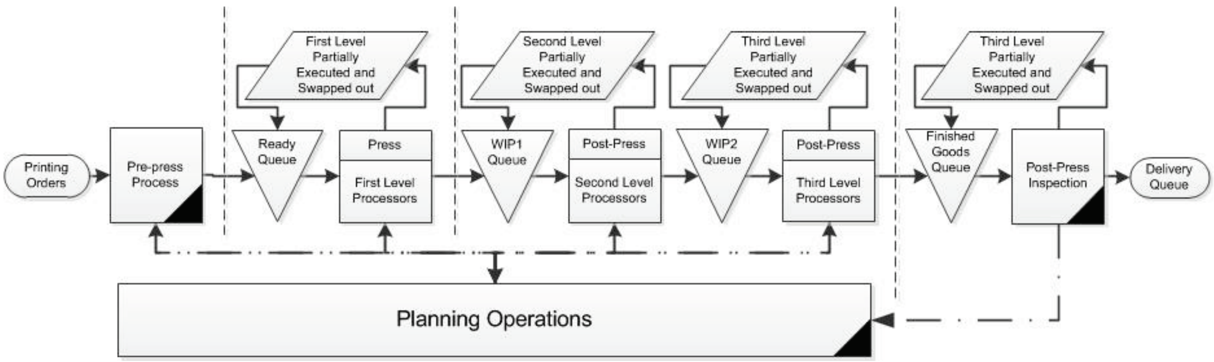
Source In-depth Interview with the printers

Analyze the conventional press and post-press planning and scheduling process

The planning for printing process and execution are different to the common simple network diagram. As picture 3 shows the first to fourth processors states of queue, execution, and e-execution for the operation scheduling and the planning operation An important notice would be printing orders may not be produced at a partial amount to the whole amount under certain circumstances. In fact, the processes are successfully at the executed or re-executed states as of the bottom

1. When a process starts from the production orders,
2. When a process turns form the running processor state to the next level waiting queue state,
3. When a process turns from the running processor state to its own level waiting queue state,
4. When a process turns from the waiting state to the running state,
5. And when a process terminates after post-press processes

Picture 3: Press and Pre-Press Conventional Scheduling Process Flowchart



Source In-depth Interview with the printers

5.2. Identify the needs for change

Pinpoint drawbacks of conventional scheduling algorithm towards printing press

Besides the exact mathematical programming scheduling methods used in printing press, heuristic and search stochastics methods are not to taken in consideration for finding the optimal solutions for both the linear and non-linear printing press processes All printers have time constraint on computation, but each task of orders are to be produced before its deadlines Therefore, all printing scheduling algorithms should take concerns of the deadline at a prioritized and significant importance Quan & Chang, 2003 Bini & Buttazzo, 2004 Chetto & Chetto, 1989 Utilization rate at its first level press processors are also important to enhance productivity and sales of printers

Core processor utilization CPU

Most of the conventional printers prefer CPU to minimize the cost while seeking profitability It is proved from previous work that constraint-based scheduling is used in print shops at all times Fromherz, Saraswat, & Bobrow, 1999 With these printing constraints carefully achieved would result a better machine utilization rate

Minimum to due date MTDD

MTTD is one of the commonly used algorithm for pull strategy firms as printers However, previous works still claims that MTTD best improves delayed jobs and job tardiness despite of adequate results on CPU utilization, flowtime, and makespan time Azmi, Bakar, Abdullah, Shamsir, & Manan, 2011

Hybrid Advance Scheduling HAS

HAS is the combination of Communication Awareness scheduling CAS with further printing algorithms CAS has proven significant advantages over local or manual scheduling for planners, and it has proven that it delivers with breakthrough improvements on machine idle time and waiting time Madheswari & Banu, 2013

The time sequence and importance of scheduler

After 47 day trails of HAS scheduling from November to December during 2015, comprising results has been shown and collected It is found that HAS scheduling contains both advantages with MTTD and CPU despite that it consumes slightly higher daily time consumed of 360 28 minutes As shown in table 9 and table 10, HAS scheduling could perform with mere close to CPU while having the flexibility of rush orders and order shifts like MTTD

Table 9 Direct observation on minute consumed on the HAS scheduling November to December 2015

Priority Day\	Number of Processors	Input the production orders	Update the production queue sheet	Prioritized the queue of each level processors	Total Scheduling Time Consumed	Human errors
Sum	13	7,067 04	4,488 4	5,738 01	25,563 74	3
Percentage	n a	33 33	40 87	25 95	33 18	n a
Average	n a	147 23	93 51	119 54	360 28	0 06
Standard Deviation	n a	74 67	31 50	8 98	34 19	0 24

Source In-depth Interview with the printers

Table 10: Results of performance indicators of HAS scheduling algorithm

Year Month	2015 11		2015 12		HAS TTL 2 month actual		HAS TTL 3 month estimate	
Job Types	Freq	QT	Freq	Freq	QT	QT	Freq	QT
X1	12	438,260	12	418,500	24	856,760	36	1,285,140
X2	30	2,383,420	27	1,890,000		4,573,420	86	6,860,130
X3	1	100,000	0	0	1	100,000	2	150,000

X4	16	378,000	8	502,000	24	880,000	36	3,353,190
X5	0	0	0	0	0	0	0	0
Y	35	5,085,880	20	3,474,500		8,560,380	83	12,840,570

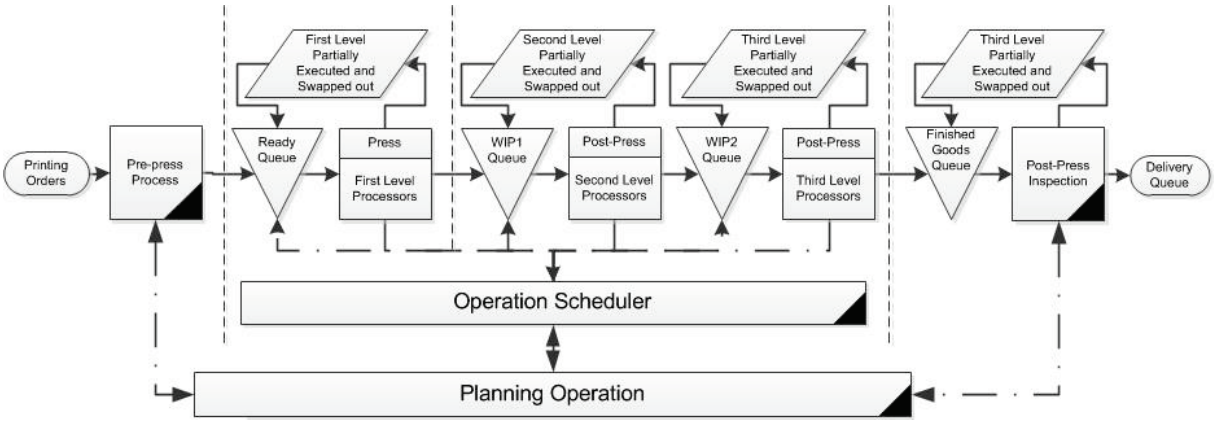
Source Documentary Records from printer of LLC

5.3. Analyze the improvement process

Innovate and implement hybrid advanced scheduling for both press and post-press process

This innovative HAS scheduling also requires a relatively alteration to the scheduling process. Picture 4 shows the first to fourth processors states of queue, execution, and e-execution for the operation scheduling and the planning operation In fact, the processes are successfully at the executed or re-executed states as of the bottom Digitalization of scheduling would identify the bottleneck of the system that uses just-in-time and optimized-production strategies   Printers desire just-in-time and production optimization strategies due to the fact that they have relatively short lead time with numerous types of raw materials and printing press machines to handle with

Picture 4: Press and Pre-Press Hybrid Multilevel Scheduling Process Flowchart



Source In-depth Interview with the printers

Collect the results of the hybrid multilevel scheduling and compared its significance

As of the previous works of comparison for optimal scheduling algorithm, results, methods, and evaluations techniques are used to determine the best performed and robust scheduling algorithm Mignon, Honkomp, & Reklaitis, 1995   Swisher & Jacobson, 1999   The time required to perform scheduling went out the longest of 360 3±74 7 minutes as demonstrated in table 11 since it requires intensive meeting and communication between the production and the planner himself

Table 1   Direct observation on minute of time consumed on the conventional scheduling progress per day

Priority\ Scheduling Algorithms	CPU	MTTD	HAS
Input the production order into the scheduling form	18 9±5 7	104 9±8 2	147 2 0±31 5
Create and update the production queue sheet	118 1±16 7	104 7±8 2	93 5±9 0
Prioritized the queue onto each distinctive level processors	79 0±21 9	37 5±4 6	119 5±34 2
Total scheduling time	215 9±44 2	247 1±21 1	360 3±74 7
Human errors throughout scheduling	0 53±0 5	1 2±1 0	0 1±0 2

Source 121 direct observations with schedulers of the LLC printer

Since to the recent introduce of HAS scheduling, there are several unfamiliarity impacting delayed orders It performed 27 5 monthly delays closely to the MTTD of 25 7 monthly delays scheduling where job delivery comes at priority in table 12 Even though all the three scheduling algorithms performed similarly with the unexpected monthly rush orders in table 13, HAS scheduling has the best order shifts frequency of 28 5 in table 14 indicating its scheduling flexibility

Table Total delayed orders from each scheduling algorithms

Priority\ Scheduling Algorithms	CPU	MTTD	HAS
Trial-1	27	15	35
Trial-2	20	22	20
Trial-3	58	40	
Monthly average	35	25 7	27 5

Table 13: Total successful rush orders accomplished with each scheduling algorithms

Priority\ Scheduling Algorithms	CPU	MTTD	HAS
Trial-1	18	9	12
Trial-2	15	11	12
Trial-3	13	19	
Monthly average	15	13	12

Table 14: Total successful order shifts and flexibility with each scheduling algorithms

Priority\ Scheduling Algorithms	CPU	MTTD	HAS
Trial-1	6	32	30
Trial-2	8	34	27
Trial-3	6	14	
Monthly average	7	26 7	28 5

6. DISCUSSION

6.1. Financial performance

The recent performance indicators of the HAS scheduling are then transformed into financial figures in table 15 It is shown that HAS scheduling best performs at an estimated annual saving of 135,776 16 THB than other scheduling algorithms Although the financial performance does not provide a break through advantage, it is an initial evidence that HAS can be further applied for more outcomes

Table Financial evaluation on the three scheduling algorithm for printers

Scheduling Algorithms		CPU	MTTD	HAS
Time consumed	result day	215 9	247 1	360 3
	cost month	7,985 32	6,259 96	0
	cost annual	95,823 84	75,119 52	0
Human errors	result day	0 53	1 2	0 1
	cost month	6,700 00	0	11,000 00
	cost annual	80,400 00	0	132,000 00
Delayed orders	result month	35	25 7	27 5
	cost month	0	18,600 00	15,000 00
	cost annual	0	223,200 00	180,000 00
Cost Savings	Total	176, 84	298, 52	312,000 00
Comparative Cost Savings	Offset total	0	,	135,776

6.2. Flexibility and opportunity evaluation

On the other hand, the HAS scheduling out performs other scheduling algorithms with 222 estimated frequencies for rush orders and order shifts shown in table 16 It is resulted similarly to the MTTD algorithms, so HAS scheduling is a definite algorithm for the pull strategy based printers

Table 16 Flexibility evaluation on the four scheduling algorithm for printers

Scheduling Algorithms		CPU	MTTD	HAS
Rush orders	Result month	15	13	12
Order shift	Result month	7	26 7	28 5
Total Flexibility	Total result Month	22	39 7	40 5
	Offset month	0	17 7	
	Offset year	0	212 4	222

7. RECOMMENDATION FOR FUTURE WORK

Despite the fact that the current hybrid advance scheduling has some significant performance on the job delays and order shifts, it still consumes a large amount of time for the planning process Moreover, it can be further applied with the pressing algorithms to perform even better financial results Once the improved version of the hybrid multilevel scheduling succeeds, printers have a high likelihood to experiment it to merely all of the pressing types

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