Research on Procurement Process Optimization of D Company's Industrial Procurement Center

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Abstract: This paper works on procurement process optimization of D company's industrial procurement center by analyzing the procurement process, building Petri net of the procurement process and Arena simulation to summarize three key processes to propose 18 univariate optimization schemes. Finally, five locally optimal schemes would be selected to be combined to be 12 multivariable optimization schemes to select the best one. And the suggestions for improving the procurement process would be given by comparing the original procurement process and the optimal scheme.

1. Introduction

Nowadays more and more people realize the importance of exercise that sports industry has a good development prospect. However, as costs continue to rise and profitability is declining, industry transformation and upgrading have become more and more important. Generally, corporate procurement costs account for 60% of sales costs, so procurement optimization is a good starting point for industrial transformation and upgrading. Although there are a lot of researches on procurement process optimization up to now, few scholars have focused on the sports industry. Therefore, it is of great practical significance to study the procurement process optimization of the industrial procurement center of D company which has an excellent sports industry chain.

D company was founded in 1976 and has been focusing on the sports market. It has a full sports industry chain that integrates development, design, procurement, manufacturing, and terminal sales. Until 2019, it has 81,754 employees worldwide, with a total of 1,350 stores in 40 countries. The revenue of D company has been steadily increasing every year from 4.9 billion euros in 2008 to 11 billion euros in 2017 with an average annual growth rate of 9.4%. This is a very good performance in terms of corporate revenue. The net profit margin of D company in China in 2017 reached 11.3%, which is still not too high for sports manufacturing companies that there is still a lot of space for D company to improve. The global organizational structure of D company can be divided into four parts, including R & D centers, brand department, production and procurement centers, and terminal retail. Among them, the production and procurement center is the most important. It has undertaken the development and design concept through the R & D center and brand department and turned it into reality to sell to the end consumer.

Many scholars have studied procurement process optimization in different ways. Among them, Wu Wanxian researched the procurement coordination of apparel companies [4], used Petri nets to analyze the procurement process and proposed an optimization plan. Tang Ling conducted a research on the optimization of the procurement process of a power company based on Petri nets and found key processes through Petri net modeling and proposed an optimization plan [3]. All the studies above have used Petri nets to optimize procurement processes which indicate that Petri net is a very effective modeling tool for analyzing complex system processes.

After proposing an optimization plan for the original procurement process, the efficiency of the plan still need to be evaluated. In this regard, many scholars have used Arena simulation to measure the efficiency data. Xue Han et al. used Arena to build a supply chain system to simulate discrete events and return performance indicators [5]; Sun Junqing et al. conducted inventory simulation optimization research based on Arena's stochastic demand and random lead time [2]. Zhao Shanshan et al. studied the dynamic adjustment of container yard based on Arena simulation [6]. Li Changjun et al. studied the performance prediction and evaluation of Arena simulation production line based on mutation theory [1].

In summary, this paper uses Petri net modeling to construct the procurement process, optimizes it and verifies the feasibility of the model. And then it analyzes the results of Arena simulation to verify the optimization efficiency. Finally, according to the conclusion of the process optimization, the suggestions for improving the procurement process of D company would be given.

2. Analysis of the Operation of D Company's Procurement Process

The procurement process of the D company's industrial procurement center include: new season style design, initial sample design, raw material/ fabric/ accessories/ initial sample development, review process, sample selection meeting, order receive, garment test, procurement and production planning, fabric production and inspection, size samples development and inspection, pre-production sample development and inspection, mass production and product packaging, shipment preparation and transportation.

D company's procurement process is divided into two periods-spring and summer, autumn and winter to repeat the process. As the market changes rapidly and the competition becomes more and more fierce, there are more kinds of products and fewer quantities each, which makes the corporate procurement work becomes more and more intense. Therefore, it is imperative to optimize and simplify the procurement process to improve the efficiency. The following are problems in the procurement process from four aspects:

(1) Long development process

The development work can be divided into two parts, including the development work before the sample selection meeting and the development work before mass production. The development work before the sample selection meeting refers to the raw material development, fabric development, accessories development and initial sample development after the initial sample design. Generally, different development work would be conducted in different groups at the same time after the design development instructions is issued by the headquarter. But there is a problem with parallel development work that if there is any problem happening during a development work process, it would also cause other development work to be reworked. For the procurement process itself, the long development process before the sample selection is also a problem that makes the subsequent work lag.

For the development work before the mass production, the fabric production will be conducted first, and then the size sample development and the pre-production sample development will be carried out separately. Although there are only three links and they are carried out in sequence, combined with the development work before the sample selection meeting, there are still a total of seven development processes, which accounts for a very high proportion of the entire process and takes a long time that the orders may occasionally be delayed. And In order to complete the order on schedule, D company would choose to rush to work regardless of cost, which would make the cost surge.

(2) Complex and redundant inspection

The inspection process of the procurement process includes the review after the completion of the initial sample development, the fabric inspection before the mass production, pre-production sample inspection, the size sample inspection, and the garment test on the first order. Multiple inspections are set up to ensure the quality of the process of design, procurement, production and sales, but too many inspections would make the entire procurement process take longer and cost more. And for the sports industry, fierce market competition and changing customer demands require companies to have better market response capabilities and be able to develop new products quickly. The complex and lengthy inspection process leads to a long response time and poor response level of the enterprise.

(3) Poor information sharing

For industrial procurement center of D company, most of the daily work communication is completed by e-mail, which cannot share information and respond to the market in time.

(4) High cost

The total operating cost and procurement and production costs of D company are higher than the target costs of their respective units. That means the cost control of the industrial procurement center needs to be improved. Excessive inspection process and long process time could cause high costs.

3. Petri Net Modeling of the Procurement Process and Arena Simulation

3.1 Petri net modeling of the procurement process

This section will perform the Petri net modeling of the original procurement process first. The model starts from the market trend prediction, and then the demand will generate the response activities, which will lead to new demands until the final product become the store new commodity, as it shows in Fig. 1. The meaning of each symbol is shown in Table 1.

Table.1. The meaning of each symbol of the Petri net model of the procurement process

Symbol	Meaning	Symbol	Meaning
S1	Market Trend Prediction	T1	New Season Style Drafting
S2	New Style	T2	Initial Sample Design
S3	Former Style	T3	Raw Material Development
S4	Developing Information	T4	Fabric Development
S5	Developed Information	T5	Accessories Development
S6	Pass	T6	Initial Sample Development
S7	Not Pass	T7	Inspection
S8	Sample Result	T8	Sampling Meeting
S9	First Order	T9	Order Received
S10	Reorder	T10	Fabric Inventory Inquiry
S11	Fabric Inventory Remain	T11	Garment Test
S12	Fabric Inventory not Remain	T12	Fabric Production
S13	Garment Test Pass	T13	Procurement and Production Planning
S14	Garment Test not Pass	T14	Re-Produce
S15	Fabric	T15	Fabric Inspection
S16	Procuring and Producing Plan	T16	Grey Cloth Drafting
S17	Fabric Test Pass	T17	Color Cloth Procurement
S18	Fabric Test not Pass	T18	Size Sample Development
S19	Grey Cloth	T19	Size Sample Inspect
S20	Color Cloth	T20	Pre-Production Sample Development
S21	Size Sample	T21	Pre-Production Sample Inspect
S22	Size Sample Inspection Pass	T22	Mass Produce
S23	Size Sample Inspection not Pass	T23	Product Packaging
S24	Pre-Production Sample	T24	Shipment Prepare
S25	Pre-Production Sample Inspection Pass	T25	Warehouse Arrival
S26	Pre-Production Sample Inspection not Pass	T26	Store Arrival
S27	Mass Produced Product	S30	Warehousing Product
S28	Well-Packaged Product	S31	Store New Commodity
S29	Product to be Transported	—	—

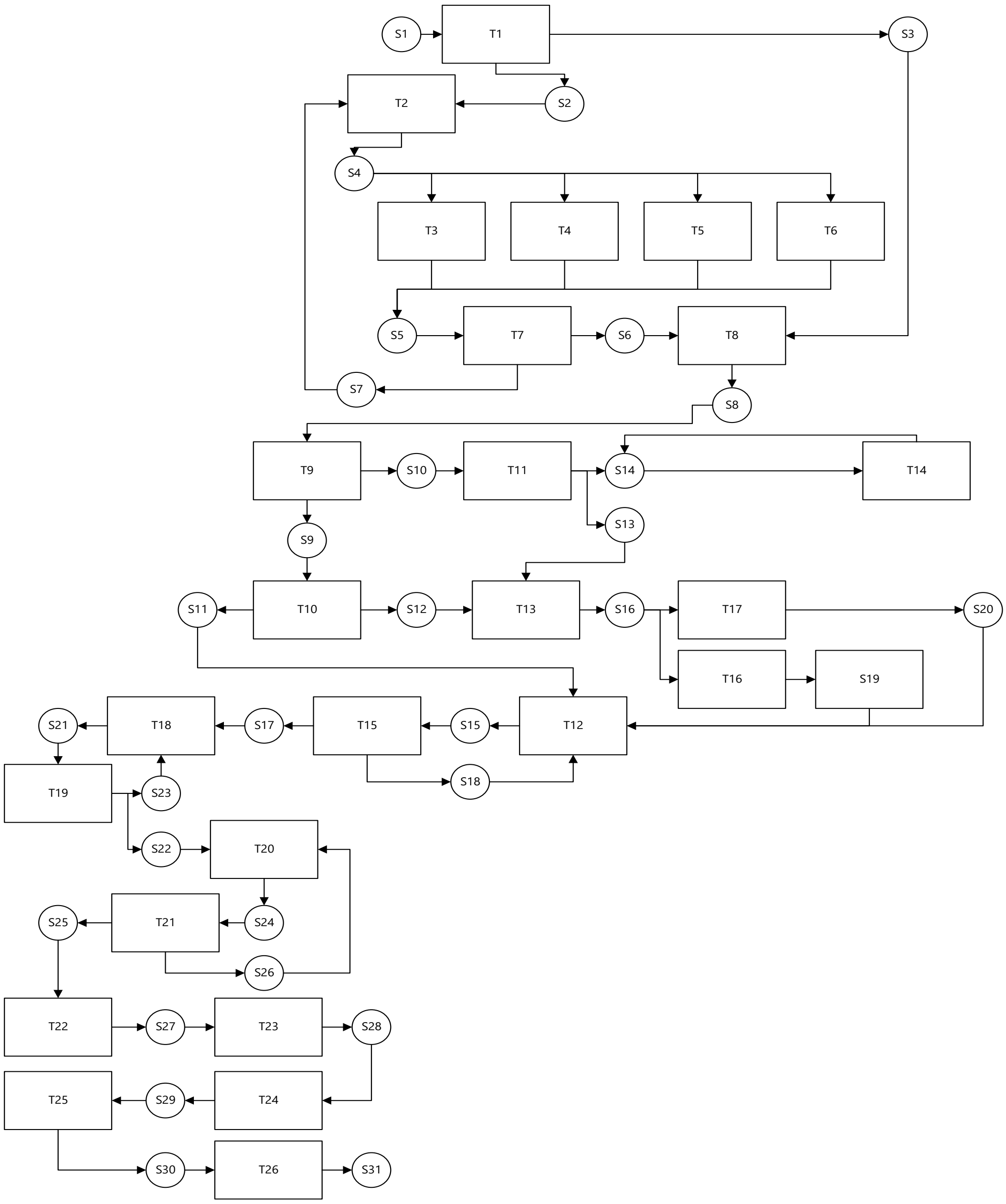

Figure 1. Petri net model of the procurement process

3.2 Mathematical analysis of Petri net model

After modeling, mathematical analysis is used to construct the matrix tables to describe the relationship between different processes. Ti caused by Si is marked as -1, and Si caused by Ti is marked as 1. Input data through constructing the matrix, if it exists a positive real vector Y, such that ATY = 0, then the Petri net model is feasible. Use Matlab to find out that Y_1T = [1,0,1,0,0,0,0,1,1,0,1,0,0,0,1,0,1,0,0,0,1,1,0,1,1, 0,1,1,1,1,1] exits. The feasibility of the model is verified.

At last, find the conflict by constructing the subnet. The existence of a conflict indicates that there are resource conflicts between processes which need to be optimized. Subnet refers to that if and only if single 1, -1, or 1 and -1 appear in the ranks. Six subnets can be found that transition T3, T4, T5, T6, T16, and T17 have concurrent resource conflicts. We know from Table 3 that these are the conflict among raw material development, fabric development, accessories development, initial sample development and the conflict between grey cloth drafting and color cloth procurement. It shows that process split is required to eliminate resource conflicts of development processes and grey cloth drafting and color cloth procurement.

Although two conflicts involved in six processes have been found, the key processes derived from the Petri net model are still relatively unreliable to construct a univariate process optimization scheme. Therefore, the next step is to create Arena simulation of the original procurement process and analyze the time consumption of the sub-processes and their relationship detailedly.

3.3 Arena Simulation and Analysis of the Procurement Process

First, count the actual operation cycle of each process and use them as the basis of parameter setting. The process cycle summary is shown in Fig. 2.

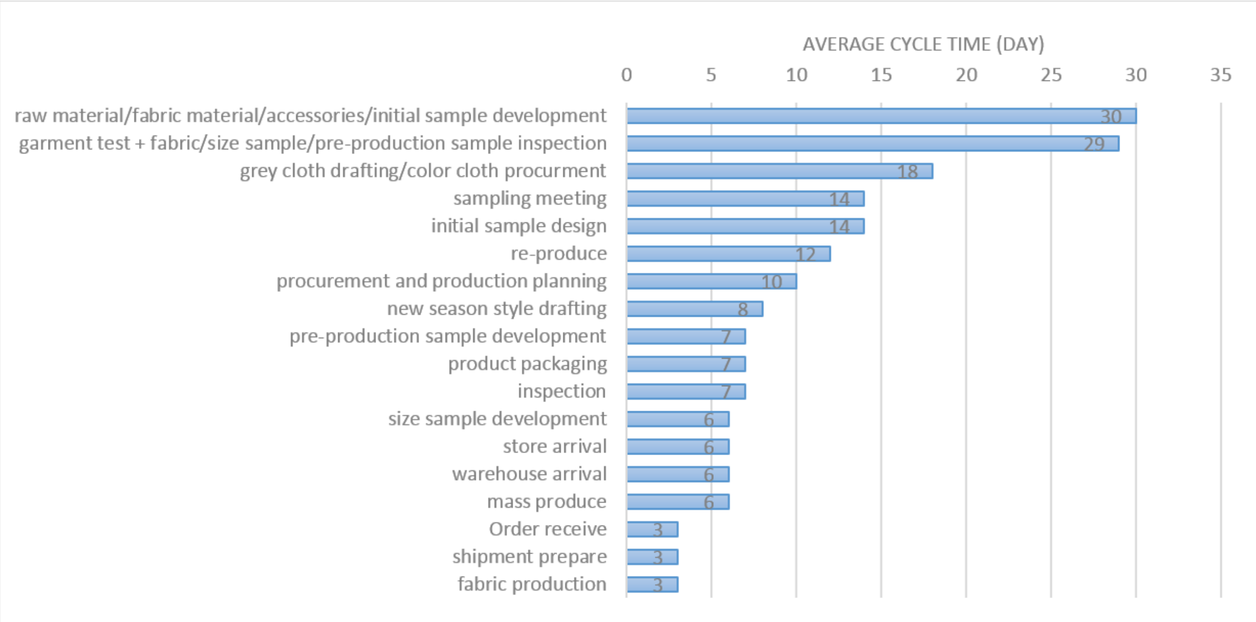

Figure 2. Average cycle time of each sub-process

And then build the Arena simulation model of the procurement process. The initial market demand for the new season is set to the Create module, and the parameter is set to Constant 183 day 1 perarrivals. At the same time, each reaction from new season design to store arrival is set to the Process module and the parameter is set to Seize Delay Release according to the cycle time. Use the Triangular module to set the average, maximum and minimum value.

The resourse priority is Medium (2). The name of the consumed resources are Resource 1 and the unit is 1. The selection module includes inspection, garment test and pre-production inspection, which use the Decide module and 2-way by Chance type and fill in the pass rate value when the condition is true. At last, the commodities uses the Dispose module with the parameters set to Record Entity Statistics.

As for the feasibility analysis of the model, this paper compares average processing time with the simulation data and the actual data. Only the difference ratio of each process is controlled within 10%, can the simulation model be considered as effective and feasible. It is proved that the difference ratio between simulation average processing time and actual average processing time before and after optimization is controlled within 6% that the model fits and has certain feasibility.

As can be seen from Fig. 2, it is obvious that raw materials/ fabrics/ accessories/ sample development, garment test + fabric/ size samples/ pre-production samples inspection and grey cloth drafting/ color cloth procurement are the emphasis of process optimization. Their average cycle time are 30, 29, 18 days, which are far more than other sub-processes.

In the previous section, it was also concluded by mathematical operation that there were resource conflicts among the development works and between grey cloth drafting and color cloth procurement, so these are the focus of process optimization.

In addition, there are five test links in the whole procurement process, including garment testing, three pre-production inspections and the inspection after the initial sample development. The test links are redundant and need to be streamlined and optimized. Therefore, we count the pass rate of each test link and optimize the process from the pass rate.

3.4 Univariate Optimization Scheme for the Procurement Process

According to 3.3, the univariate optimization scheme is shown as Table 2.

Table.2. Univariate optimization scheme

Plan No.	Sub-process which need to be optimized	Particular measure
1	raw materials / fabrics / accessories / sample development	Separate to raw materials→ fabrics→accessories→sample development
2		Separate to raw materials→fabrics, accessories→sample development
3	garment testing + fabric / size samples / pre-production samples inspection	Delete garment testing
4		Combine fabric / size samples / pre-production samples inspection
5		Combine fabric / size samples / pre-production samples inspection, and increase the pass rate of combination to 80%
6		Combine fabric / size samples / pre-production samples inspection, and increase the pass rate of combination to 85%
7		Combine fabric / size samples / pre-production samples inspection, and increase the pass rate of combination to 90%
8		Combine garment testing and fabric / size samples / pre-production samples inspection
9		Combine garment testing and fabric / size samples / pre-production samples inspection, and increase the combination pass rate to 70%
10		Combine garment testing and fabric / size samples / pre-production samples inspection, and increase the combination pass rate to 75%
11		Combine garment testing and fabric / size samples / pre-production samples inspection, and increase the combination pass rate to 80%
12		Combine garment testing and fabric / size samples / pre-production samples inspection, and increase the combination pass rate to 85%
13		Combine garment testing and fabric / size samples / pre-production samples inspection, and increase the combination pass rate to 90%
14		Delete garment testing + combine fabric / size samples / pre-production samples inspection
15		Delete garment testing + combine fabric / size samples / pre-production samples inspection, and increase the combination pass rate to 80%
16		Delete garment testing + combine fabric / size samples / pre-production samples inspection, and increase the combination pass rate to 85%
17		Delete garment testing + combine fabric / size samples / pre-production samples inspection, and increase the combination pass rate to 90%
18	grey cloth drafting / color cloth procurement	Separate to grey cloth drafting→color cloth procurement

The next step is to improve the efficiency of each optimization scheme through the simulation test, and select the optimal combination to form the optimization scheme.

4. Analysis of optimization scheme

4.1 Analysis of Univariate Optimization Scheme

Verify the 18 optimization schemes proposed in Table 2. The main evaluation standard is the total process time. Simulates the procurement process before and after the optimization and the unit of time and benchmark are set as days. Each operation length is 183 days, and simulates 1000 times for large sample analysis. The running speed of the simulation is set to be 30 units each time. Constructs the optimization model and simulate it to analyze the optimal efficiency. The result is shown in Table 3.

Table.3. Simulation process time of univariate optimization scheme

Scheme No.	Average processing time (day)	Average waiting time (day)	Average total time (day)
Original process	148.21	19.17	167.38
1	143.34	7.69	151.04
2	145.34	12.56	157.91
3	141.61	9.76	151.37
4	139.41	12.05	151.46
5	137.48	9.72	147.20
6	136.12	6.69	142.81
7	133.35	5.88	139.23
8	142.07	23.03	165.10
9	139.23	14.44	153.67
10	137.23	12.29	149.52
11	134.13	9.02	143.15
12	131.71	6.47	138.18
13	128.95	4.93	133.88
14	134.21	7.66	141.87
15	130.65	5.12	135.77
16	129.31	4.67	133.98
17	127.74	4.15	131.89
18	147.37	14.64	162.00

From the table above, compared with the original process, each optimization scheme has reduced the average total processing time and average processing time to different degrees, while the average waiting time fluctuates. This situation fits the reality, because all optimization schemes is univariate, the optimization of sub-processes will lead to a reduction in average processing time but may increase the overall operation waiting time. However, the average total time is optimized to different degrees compared to the original process that these 18 solutions are still feasible.

It is certain that the optimization of a single link may not be enough. In order to obtain the optimal solution, three local optimal solutions need to be selected from these eighteen solutions and combined to test whether there is a better scheme.

Summarize the efficiency of each core links optimization plan that the optimal schemes of each core link are 1, 17 and 18, with the optimization efficiency 9.76%, 21.20%, and 3.21% respectively. Simultaneously, to be more accurate, also select second optimal schemes in raw materials / fabrics / accessories / sample development and garment testing + fabric / size sample / pre-production. The selected combined schemes are shown below.

Table.4. Local optimal selected scheme

<table>
<tr><th>Scheme No.</th><th>Key process</th><th>Optimal scheme</th></tr>
<tr><td>1</td><td rowspan="2">raw materials/ fabrics/ accessories / sample development</td><td>Separate to raw materials→fabrics→accessories→sample development</td></tr>
<tr><td>2</td><td>Separate to raw materials→fabrics and accessories→sample development</td></tr>
<tr><td>13</td><td rowspan="2">garment testing + fabric / size samples / pre-production samples inspection</td><td>Combine garment testing and fabric / size samples / pre-production samples inspection and increase the combination pass rate to 90%</td></tr>
<tr><td>17</td><td>Delete fabric inspection, Combine size samples / pre-production samples inspection and increase the combination pass rate to 90%</td></tr>
<tr><td>18</td><td>grey cloth drafting / color cloth procurement</td><td>Separate to grey cloth drafting→color cloth procurement</td></tr>
</table>

4.2 Analysis of Multivariate Optimization Scheme

According to the previous section, propose 12 multivariate optimization schemes and summarize their efficiency as Table 5 shows.

Table.5. The efficiency of multivariate optimization scheme

Combined scheme	Average processing time (day)	Average waiting time (day)	Average total time (day)	Optimal efficiency (%)
Original process	148.21	19.17	167.38	—
1+17+18	126.75	3.41	130.16	22.24
2+17+18	127.42	2.94	130.36	22.12
2+17	126.89	3.49	130.39	22.10
2+13+18	128.18	3.39	131.56	21.40
1+17	127.03	4.71	131.74	21.29
2+13	127.95	3.90	131.85	21.23
1+13+18	128.20	4.16	132.37	20.92
1+13	128.85	5.89	134.74	19.50
17+18	129.82	5.81	135.63	18.97
13+18	129.49	6.39	135.89	18.81
1+18	145.81	10.07	155.88	6.87
2+18	147.80	15.20	162.99	2.62

From Table 5, the optimal solution is the combination of 1 + 17 + 18, that is, split the development process of raw materials / fabric / accessories / samples into raw material development → fabric development → accessories development → initial sample development, delete garment testing + fabric / size samples / pre-production sample inspection and increase pass rate of the combination to 90% and split grey cloth drafting / color cloth procurement into grey cloth drafting → color cloth procurement .

4.3 Petri Net Modeling Analysis of the Optimal Scheme

After the optimal scheme is obtained from the above section, we can use Petri net modeling to analyze its feasibility and practicality. The procurement process of the optimal solution is shown below.

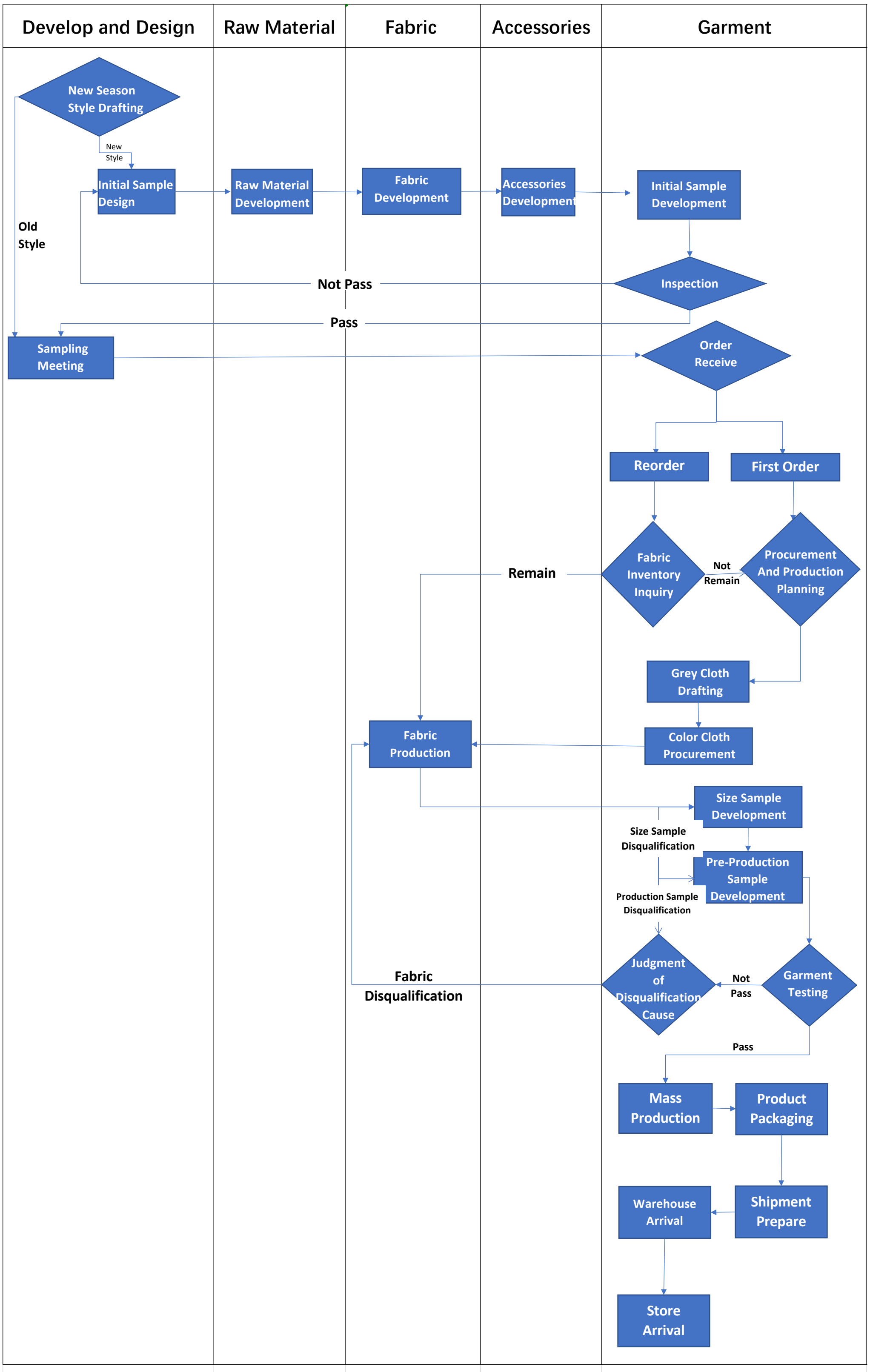

Figure 3. Procurement process of the optimal scheme

Similarly, build the Petri net model of the procurement process from optimal solution, and construct an association matrix. For the optimized Petri net, X2T=[1,0,1,0,0,0,0,0,0,0,1,0,1,0,0,1,0,1, 0,1,1,1,0,1,0,0,0,1,1,1,1] also exits that the feasibility of the model is verified. And we can also learn from the association matrix that there is no conflict in the optimization model and the process also becomes more simplified. Therefore, the feasibility verification of the optimal scheme model is completed.

4.4 Analysis and Comparison of the Original Procurement Process and the Optimal Scheme

At last, we analyze and compare the original procurement process and the optimal scheme mainly in six aspects:

(1) The average operation time of each sub-process

Table.6. The operation time of the original process

Process	Average Processing Time (Day)	Average Waiting Time (Day)	Total Time (Day)
Procurement and Production Planning	10.36	0.60	10.96
Warehouse Arrival	6.00	1.64	7.64
Product Packaging	7.39	1.30	8.68
Pre-Production Sample Inspection	4.00	1.27	5.28
Pre-Production Sample Development	6.99	0.96	7.95
Garment Testing	9.74	0.71	10.45
Size Sample Inspection	8.68	0.80	9.49
Size Sample Development	5.99	0.74	6.73
Shipment Prepare	3.00	1.39	4.39
Initial Sample Design	13.65	1.16	14.81
Mass Produce	5.99	1.25	7.24
Order Receive	2.99	0.78	3.77
Develop	29.97	0.93	30.90
Store Arrival	6.00	2.00	8.00
Fabric Inspection	5.99	0.77	6.75
Fabric Production	3.00	0.78	3.77
Grey Cloth Drafting and Color Cloth Procurement	17.99	0.69	18.68
Inspection	7.03	0.83	7.86
New Season Style Drafting	8.00	0.91	8.91
Sample Meeting	14.34	0.92	15.25
Re-Produce	12.02	0.83	12.86
Total	148.21	19.17	167.38

Table.7. The operation time of optimal scheme process

Process	Average Processing Time (Day)	Average Waiting Time (Day)	Total Time (Day)
Procurement and Production Planning	10.36	0.11	10.47
Warehouse Arrival	5.99	0.27	6.27
Product Packaging	7.00	0.32	7.32
Pre-Production Sample Development	6.98	0.11	7.10
Garment Testing	9.66	0.10	9.76
Size Sample Development	5.66	0.15	5.81
Shipment Prepare	3.02	0.44	3.46
Initial Sample Development	12.01	0.10	12.12
Initial Sample Design	13.67	0.33	14.00
Mass Production	5.99	0.10	6.10
Order Receive	2.99	0.14	3.14
Accessories Development	5.01	0.22	5.23
Disqualification Management	9.09	0.06	9.15
Store Arrival	6.01	0.34	6.35
Fabric Development	7.00	0.25	7.25
Fabric Production	3.02	0.12	3.14
Grey Cloth Drafting	9.98	0.16	10.14
Color Cloth Procurement	8.00	0.14	8.14
Inspection	6.98	0.11	7.10
New Season Style Drafting	7.99	0.15	8.14
Sample Meeting	14.01	0.20	14.21
Material Development	6.00	0.22	6.22
Total	126.75	3.41	130.16

Summarize the operation time of each sub-process from original process and the optimal scheme as Table 6, 7 show.

Compare the two tables, although the optimal scheme adds a sub-process, the operation time of each sub-process and total average processing time and total average waiting time and total time are all less than those of the original process, which reflect the effect of the optimization.
And then focus on the key processes shown in Table 8.

Table.8. The operation time of different key process

Key Processes \ Operation Time	Average Processing Time(Day)		Average Waiting Time(Day)		Total Time (Day)	
	Original	Optimal	Original	Optimal	Original	Optimal
Raw Materials/Fabrics/ Accessories/Sample Development	29.97	30.02	0.93	0.79	30.9	30.82
Garment Testing + Fabric/ Size Samples/ Pre-Production Samples Inspection	28.41	18.75	3.55	0.16	31.97	18.91
Grey Cloth Drafting / Color Cloth Procurement	17.99	17.98	0.69	0.3	18.68	18.28

From the table above, we can see that the effect of optimization is very obvious. The optimization efficiency of garment testing + fabric/size samples/pre-production samples inspection is optimal, up to 95.49%, which illustrates that the improvement in the optimal scheme makes the logical relationship between each process better and reduces the waiting time.

(2) Processing time

Summarize the processing time of the original procurement process and the optimal scheme as Table 9 shows.

Table.9. The processing time of the original process and the optimal scheme

	Original process (Day)	Optimal scheme (Day)
Maximum	503.05	417.45
Minimum	84.19	74.60
Average	167.38	130.16

Processing time is most consuming and the main time logic of the procurement process. As can be seen from the table above, compared with the original process, the optimal scheme has different degrees of optimization effects from the average to the maximum and minimum value.

(3) Waiting time

Summarize the waiting time of original process and the optimal scheme as it shows in Table 10.

Table.10. The waiting time of the original process and optimal scheme

	Original process (Day)	Optimal scheme (Day)
maximum	269.45	162.22
minimum	0.00	0.00
average	3.41	19.17

Waiting time is second most consuming, and the main stuck logic. Compared to the original process, the optimal scheme has effect on both average and maximum value. As the minimum value are both 0, there is no comparability. But for the maximum, there is a significant improvement showing the probability of long-term stuck is greatly reduced.

(4) Total operation time

Summarize the total operation time of the original process and the optimal scheme as shown in Table 11.

Table.11. The total operation time of the original process and optimal scheme

	Original process (Day)	Optimal scheme (Day)
maximum	503.05	417.45
minimum	84.19	74.60
average	167.38	130.16

The total operation time is the main time logic and the main stuck logic of the whole procurement process. Compared to the original process, optimal scheme also has different optimization effects on maximum and average value.

(5) Optimization efficiency on total operation time

It is difficult to clearly show the optimization efficiency by comparing the original process and the optimal scheme numerically. Summarize the optimization efficiency of the total time, waiting time and processing time and classify them by the mean value, minimum value and maximum value as it shows in Table 12.

Table.12. The optimization efficiency of the original process and the optimal scheme

	Total time	Waiting time	Processing time
maximum	17.02%	11.39%	22.24%
minimum	39.80%	0.00%	82.19%
average	9.52%	9.83%	14.48%

According to the table above, the optimization efficiency is obvious. For the minimum value, the optimization efficiency of the processing time is 82.19% that the fastest cycle is greatly improved. For the maximum value, the optimization efficiency of the processing time also reach 22.24%, which illustrates the optimal solution also reduce the peak value. Finally, for the average value, the optimization rate can be basically controlled at 10%.

(6) Time structure

In addition to optimization efficiency, we can also study the ratio between the processing time and the total time, and the ratio between the waiting time and the total time of the original process and the optimal scheme. Since the processing time represents the time required for each sub-process, and the waiting time is the time for the sub-process stuck. Therefore, the proportion of waiting time should be reduced to improve the time structure. Summarize the time structure of the original process and the optimal scheme as Table 13.

Table.13. Time structure of original process and optimal scheme

	Original process	Optimal scheme
Processing time rate	88.55%	97.38%
Waiting time rate	11.45%	2.62%

Compared to the original process, the ratio of waiting time descends from 11.45% to 2.62%, which illustrates that the optimal scheme owns a more efficient time structure.

4.5 Suggestions for Improvement of the Procurement Process

According to the optimal scheme, six suggestions are given as follow:

(1) Separate development work in turn

The development works of D company are redundant and should be separated to be conducted in turn instead of being conducted at the same time like: raw materials→fabrics→accessories→sample development, which can ensure that the problems appear in one link will not cause reworking in other links.

(2) Delete garment test

The garment test was designed to ensure product quality, but because there are still a lot of inspection works before mass production, the garment test becomes redundant. Remove it can simplify the entire procurement process and reduce the operation time to improve market responsiveness.

(3) Combine pre-production inspection

Combine three pre-production inspections including fabric, size sample and pre-production sample inspection to form a garment inspection. This can avoid excessive inspection sections, and post inspection can also ensure the quality before the mass production.

(4) Separate grey cloth drafting and color cloth procurement

The grey fabrics and the colored fabrics procurement are conducted concurrently like the development works originally. Separate them and conduct in turn will also help optimize the entire procurement process.

But at the same time, we should also consider the risks of reforming:

(1) The time cost raised by changing parallel into serial work

Theoretically, parallel works is less time-consuming. Changing from parallel to serial works will increase waiting time. But it still has a large optimization effect that if the pass rate of the optimal scheme and original process are both 100%, the optimal scheme still has a total processing time of 146.22 less than 155.05 of the original process. The optimal efficiency is shown as Table 14.

Table.14. The optimal efficiency of changing from parallel to serial works

	Processing time (Day)	Waiting time (Day)	Total time (Day)
Parallel	146.89	8.16	155.05
Serial	143.22	2.99	146.22
Optimal efficiency	2.50%	63.28%	5.69%

(2) Delete garment test may increase the risk of mass production

Delete garment test means that the re-production work after failing the garment test would be canceled also, which reduces a lot of time for the entire procurement process, but also increases the risk of failing the test after that could not respond the market quickly.

(3) Combine three pre-production inspections may decrease on-time delivery rate

Combine three pre-production inspections can greatly optimize the processing time and waiting time, but since the mass production is near, if the test fails, it must go through the process again, which will increase the risk of reducing the on-time delivery rate and cause delays.

(4) The division of responsibility after optimization

How to divide the responsibility for the risk of delayed delivery after those sub-processes combined is worth thinking. The tests were originally conducted by different groups and the responsibility were clearly divided. The combined processes may raise the risk of testing and it is difficult to blame.

In summary, this section gives the suggestions and lists the potential risks of reforming for the procurement center of D company. If a company wants to get improved, it must be optimized and also need to solve the potential risks. We hope this research can be a reference from the theoretical level.

5. Conclusion

This paper has conducted a relatively superficial optimization study on the procurement process of the industrial procurement center of D company, and there are still many areas can be improved:

(1) This paper simplifies the procurement process in order to describe it briefly. The actual procurement process of industrial procurement center is more complicated. Further study should consider the detail of the process deeply in order to fit the actual situation more realistically.

(2) When constructs the Petri net model, this paper uses the most basic one instead of some more complicated models to do the analysis. Using those complicated models can do more effective analysis, for example, we can use colored Petri nets or stochastic Petri nets to simulate, and Markov chains to establish isomorphic relationships for key process optimization analysis.

(3) This paper only use processing time as evaluation index, which cannot show the optimization efficiency fully in many aspects. Further study could consider the evaluation from the aspects of cost, profit, personnel and resources.

References

[1] Li Changjun, Liu Jingye, Li Bo. 2018. Performance prediction and evaluation based on the variability theory in production lines using arena simulation. *Wireless Pers Commun*, Vol. 103 (1).

[2] Sun Junqing, Xiao Zhixian, Liu Fenglian. 2011. Simulation and optimization of two-echelon inventory with stochastic demand and lead time based on arena. *Logistics Technology*, Vol. 30 (7).

[3] Tang Ling. 2015. The optimization of power Construction Corporation purchasing process based on Petri net. *South China University of Technology*.

[4] Wu Wanxian. 2014. The optimized research of procurement coordination mechanism for the MS apparel enterprise. *Fuzhou University*.

[5] Xue Han, Wang Yongming, Zhao Shuai. 2016. Optimization for serial supply chain's control strategy based on mesh adaptive direct search and simulation. *Computer Integrated Manufacturing Systems*, Vol. 22 (5).

[6] Zhao Shanshan, Chu Xing, Huang Yongkun. 2016. Dynamic Adjustment of Container Yard Free Storage Period Based on Arena. *Logistics Technology*, Vol. 35 (9).