Organizational Results Research Report

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Improvement of Sign Manufacturing Process at the MoDOT Sign Production Center

Prepared by Missouri Transportation Institute and Missouri Department of Transportation

FINAL REPORT

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Improvement of Sign Manufacturing Process at the Sign Production Center

Prepared for the

Missouri Department of Transportation
Organizational Results

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The investigation was conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.

16. Abstract

A MoDOT key performance criterion is to reduce the Sign Production Center's cycle time (order entry to delivery) from 5.2 weeks to 2 weeks for stock signs and from 14.6 weeks to 4 weeks for custom signs. To obtain the 2 week stock sign and 4 week custom sign delivery goals; and meet MoDOT's increasing sign volumes using existing practices would cost approximately $2.75 Million. However, since the need for MoDOT is to significantly improve sign delivery and meet the growing demand for signs without increasing people or costs, this study offers "Twenty Solutions" that if implemented will enable the performance objectives to be satisfied with minimal capital investment.

Using state-of-the-practice tools from the Industrial and Systems Engineering profession a comprehensive system-wide analysis of the sign procurement to production to delivery process was conducted. Current lead time performance measures were developed to provide a base line for the study. A "Lean Manufacturing Assessment" was conducted to compare the sign shop to industry norms. A detailed "Value Stream Analysis" was conducted that focused on the sources of variability and locations of process bottlenecks that were impeding overall system performance. Areas identified for improvements were found at both district and shop levels. Issues at the district level included: ordering process, inventory management, rush orders, information visibility, and data coding / flow. Issues at the shop level included: demand forecasting, production planning, rush orders, work force availability, product flow, space utilization, inventory control, crew skill, and shipping processes.

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Executive Summary

The primary objective of this study was to conduct a systems evaluation of the Sign Production Center in order to provide multi-phased recommendations to improve sign manufacturing operations. A MoDOT key performance criterion is to reduce the Center's cycle time from order entry to delivery from 5.2 weeks to 2 weeks for stock signs and from 14.6 weeks to 4 weeks for custom signs.

To obtain the 2 week stock sign and 4 week custom sign delivery goals; and meet MoDOT's increasing sign volume using existing practices would cost approximately $2.75 Million. MoDOT would require additional:

- Manufacturing / inventory space (approximately 20,000 sq. ft). for $2,000,000,
- FTE/overtime (approximately 5 FTE) for $250,000 annually
- Production equipment approximately $500,000.

However, since the need for MoDOT is to significantly improve sign delivery and meet the growing demand for signs without increasing people or costs, this study offers "Twenty Solutions" that if implemented will enable the performance objectives to be satisfied with minimal capital investment.

Using state-of-the-practice tools from the Industrial and Systems Engineering profession a comprehensive system-wide analysis of the sign procurement to production to delivery process was conducted. Current lead time performance measures were developed to provide a base line for the study (5.2 weeks for stock signs and 14.6 weeks for custom signs). A "Lean Manufacturing Assessment" was conducted to compare the sign shop to industry norms. The score for the Sign Shop was 36 out of 121 (average for industry is 55). A detailed "Value Stream Analysis" was conducted that focused on the sources of variability and locations of process bottlenecks that were impeding overall system performance. Areas identified for improvements were found at both district and shop levels. Issues at the district level included: ordering process, inventory management, rush orders, information visibility, and data coding / flow. Issues at the shop level included: demand forecasting, production planning, rush orders, work force availability, product flow, space utilization, inventory control, crew skill, and shipping processes.

Key conclusions and recommendations (all 20 solutions are shown on the following table):

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- Improving the ordering and scheduling procedures in the shop and the districts (solutions #4, 5, 12, 14, 15, 16, 20) requires no capital investment and results in over 50% of the savings. Some IT systems programming may be required.
- Improving the manpower utilization and with an improvement in Value Stream length on the production floor (solutions # 1, 2, 8, 9) will greatly improve overall cost effectiveness, increased productivity, reduced overtime, system inventory reduction, increased resource utilization and lead time performance for approximately 30% of the savings.
- Implementation of all 20 solutions using a 4 phased implementation schedule is recommended so that results will start to be realized within 4 weeks.

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Summary Table of Proposed Solutions

#	Proposed Solutions	Scope	Type of change	Benefit/Cost Ratio
1	Worker leave forecast for all sign shop staff	Sign Shop	Organization	7.5
2	Schedule production plan in advance based on orders received to anticipate manpower and raw materials needed	Sign Shop	Organization	4.33
3	Utilize different pre-packing and strapping configurations	Sign Shop	Production	3.5
4	Redistribute order entry duties	Sign Shop	Organization	3.0
5	Create schedule supporting batching and reduced setup time.	Sign Shop	Organization	2.75
6	Discuss supplier's quality control measures	Sign Shop	Production	2.5
7	Reschedule / Renegotiate shipping for more frequent, shorter trips	Sign Shop	Production	2.33
8	Implement pull system on the production floor.	Sign Shop	Production	2.0
9	Improve shop floor layout for material flow, access and visibility.	Sign Shop	Production	1.86
10	Design smaller carts/crates for direct packing and delivery	Sign Shop	Production	0.78
11	Change drying techniques to improve efficiency	Sign Shop	Production	0.75
12	Simplify the order entry process by linking Sign Track to FMS system	Sign Shop	Organization	0.67
13	Access to district inventories to improve forecasting.	Districts	IT	3.67
14	Define rush orders	Districts	System	3.25
15	Implement district quarterly forecast system	Districts	System	2.6
16	Broadcast short-term sign production schedule to all districts	Districts	System	1.75
17	Track and reuse temporary signs	Districts	IT/System	1.0
18	Improve FMS system to improve information visibility and accuracy	Districts	IT	0.71
19	Due dates for orders during inventory updates	Districts	System	0.68
20	Standardize signs number throughout the system.	Districts	IT/System	0.33

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1.0 Introduction

MoDOT's Traffic Operations group desires to evaluate the Sign Production Center to determine what improvements could be made to promote cost effective and timely sign manufacturing. The Sign Production Center employs 11 people who are responsible for producing all maintenance sign needs within MoDOT (approximately 180,000 annually).

This research project is part of a broader effort to improve operations at the Sign Production Center. A concurrent project is underway to automate the existing data entry process via the implementation of SignCAD's SignTrack software This project will interface with it via the development of supporting inventory policies and procedures. This project specifically assesses the current capabilities of the MoDOT's Sign Production Center and provides an analysis of how processes could be improved to provide better service to MoDOT at a lower cost. The manufacturing systems engineering analysis identifies the disparity between current manufacturing practices and state-of-the-art manufacturing practices. A prioritized list of improvement opportunities is developed for consideration by the MoDOT Sign Production Center.

2.0 Study Objectives

The primary objective of this study is a systems evaluation of the Sign Production Center so as to provide multi-phased recommendations to improve sign manufacturing operations. The study will specifically answer the following questions:

1. How effective are the current processes used at the sign production center?
2. What improvements could be made to the sign production center that will impact overall cost effectiveness and delivery timing?

A MoDOT key performance criterion is to reduce the Center's cycle time from order entry to delivery to 2 weeks (from 5.2 weeks a 160% improvement) for stock signs and 4 weeks (from 14.6 weeks a 265% improvement) for custom signs, while not increasing the current FTE count or cost.

3.0 Study Approach and Procedures

The primary objective of this study is a systems evaluation of the Sign Production Center so as to provide multi-phased recommendations to improve sign manufacturing operations.

The general approach taken is:

1) Determination of the sign shop performance objectives and assessment of the current system with respect to these performance objectives
2) Analysis of the production system to determine what is limiting performance and development of solutions to improve performance
3) Generation of solutions and evaluation of system performance changes due to implemented solutions

The research team consists of Dr. James Noble as Principle investigator, with co-PI's: Dr. Cerry Klein and Mr. Charles Nemmers, P.E. Drs. Noble and Klein have teamed to lead the manufacturing systems engineering study and overall analysis on the project. Mr. Nemmers has provided administrative oversight and quality evaluation for the project.

1. Analysis of the MoDOT Sign Production Center was initiated by determining the appropriate performance objectives for the center, and then the center's current operation was assessed with respect to these performance objectives. MoDOT personnel were interviewed and supplied access to current performance data.

2. Tasks focused on the reengineering of information flows, data entry associated with order entry, order tracking and inventory management, and inventory policies and procedures. The Center was studied in detail via the construction of information flow diagrams and value stream (VS) maps to capture specifics on current operations. MoDOT personnel assisted in the definition of the current information flow requirements and procedures.

- Effort was made to collaborate with a recently contracted MoDOT software vendor, SignCAD, in their work to automate the Sign Production Center information flow. Due to the fact that SignCAD completed the job flow diagrams and prototype screens developed prior to the start of this project, the emphasis of this project was on the development of improved inventory control policies and procedures needed to obtain the full benefit of the SignCAD implementation.

3. Tasks focused on the assessment of Center operations from both a procedural and process perspective, followed by development of solutions prioritized to improve center performance based on best practices and technologies. MoDOT personnel assisted in the definition of current operational procedures.

- VS maps formed the basis for a detailed resource utilization analysis, constraint analysis (with respect to both procedural and process bottlenecks) and variability analysis (with respect to both process and flow variability) to determine current center performance.
- Solutions were developed to reduce overall cycle time for the production process, reduce overall system inventory levels while maintaining desired service levels, improve resource utilization and lower costs. This is achieved via the adoption of "best manufacturing practices" such as: 1) continuous, one-piece flow, 2) 5S *(i.e. Lean Manufacturing housekeeping)* 3) standard work, 4) inventory reduction, 5) mistake-proofing, 6) quick changeover, 7) total productive maintenance, 8) visual management, and 9) workspace layout.
- Throughout the project solutions generated to address include operational changes (e.g. setups, quality, production control, inventory systems, etc.) and structural changes (e.g., facility restructuring, appropriate technology, pull systems, MIS changes, etc.).

4. As MoDOT implements recommended solutions, the results will be evaluated to ensure that the desired performance improvements are achieved. MoDOT personnel will be needed in the assessment and implementation of proposed solution approaches.

4.0 Results and Discussion

4.1 Analysis of Sign Production Center performance measurement system

Initial evaluation of the Sign Shops performance measurement system revealed that the following data was being collected to support performance assessment: Weekly production quantity (Silk screen, White on Green, Structural signs), Man-hours worked, Signs on Order, Signs on Hand, Blank Inventory).

Utilizing a performance measurement system evaluation process developed by Tangen (2004) the current performance measurement system was evaluated. Overall, the current system scored 2.1 out of 7.0 with respect to the degree that the current system fulfills the requirements of a performance measurement system. The rationale behind this overall level of fulfillment is primarily based on the fact that the data collected is not supporting the analysis of overall operations sufficiently well so as to provide the ability to utilize it for operations improvement. Further comments with respect to specific performance measurement system requirements can be found in Table 1. Additional evaluation of the specific data currently collected can be found in the Appendix.

Next, since the desire of MoDOT management is to assess shop performance based on a lead time of 2 weeks for stock signs and 4 weeks for custom signs, an analysis based on a sample of all 2004 sign requisitions was conducted. Requisitions from five of ten districts were sampled (a total of 172 requisitions) to determine the lead time from requisition/order date to sign ticket completion (this approach only provided an estimate of overall lead time as the time from job ticket completion to district receipt of the sign was not available from the data). Table 2 provides the results from this analysis. The results of the analysis show that the average time for stock signs to be completed was 26 days (including weekends) or 3.7 weeks and for custom signs the lead time ranged from 41.3 to 86.2 days or 5.6 to 12.3 weeks, with an overall average requisition time of 10.4 weeks. Figure 1 below gives the distribution for all 401 shipments contained in the requisition sample taken. From this it is possible to see for a given number of days what percentage of all shipments had occurred. (note: further analysis of the lead time performance by ticket type can be found in the Appendix).

One desired use of this data was to set lead time estimates for the current SignTrack implementation in order to provide a performance benchmark. It was suggested that a Six Sigma approach be utilized, however, based on the large standard deviations for the current lead time performance a + 3 Sigma performance level would not be meaningful. Rather it is recommended that a performance benchmark be initially set at the average, then as the sign shop improvements that are recommended latter in this report are implemented the average and variation of the benchmark performance should decrease to the point that a Six Sigma performance level could be adopted.

Table 1 – Performance Measurement System Analysis

Requirements to be fulfilled by existing Performance Measurement System	**Degree of Fulfillment** (Ave = 2.1 / 7.0)	**Comments**
General	(7/28 = 25%)	
1. Provides accurate information	1 **2** 3 4 5 6 7	lagging and incomplete
2. Supports objectives	**1** 2 3 4 5 6 7	objectives needs to be stated clearly throughout organization
3. Guards against sub-optimization	**1** 2 3 4 5 6 7	no system perspective
4. Limited number of measures	1 2 **3** 4 5 6 7	few - but need better focus
Types of Performance Measures	(7/21 = 33%)	
1. Traditional criteria	1 2 3 **4** 5 6 7	budget / production analysis
2. Non-financial criteria	1 **2** 3 4 5 6 7	inventory tracked - but accuracy is suspect
3. Causal relationship	**1** 2 3 4 5 6 7	no linkages between measures criteria and objectives
Stakeholders Involved	(5/14 = 36%)	
1. Internal needs considered	1 2 **3** 4 5 6 7	not addressing desired performance measure, but some local measures
2. External needs considered	1 **2** 3 4 5 6 7	no customer oriented measures
Hierarchical Levels in System	(6/21 = 29%)	
1. Top-levels covered	**1** 2 3 4 5 6 7	none
2. Mid-levels covered	1 2 **3** 4 5 6 7	aggregate production - needs focus
3. Lower-levels covered	1 **2** 3 4 5 6 7	not sufficient detail
Time Horizon	(4/14 = 29%)	
1. Short-term objectives covered	1 2 **3** 4 5 6 7	few covered
2. Long-term objectives covered	**1** 2 3 4 5 6 7	none covered
Information Architecture	(8/21 = 38%)	Note: Sign Track will significantly impact this part of the assessment
1. Information easily accessible	1 **2** 3 4 5 6 7	limited number individuals
2. Information accessible by correct people	1 2 3 **4** 5 6 7	focus on supervisors, not shop floor or management
3. Computerized information	1 **2** 3 4 5 6 7	DOS program
Other	(1/7 = 15%)	
1. Processes for system evolution	**1** 2 3 4 5 6 7	not considered yet

Table 2 – 2004 Lead time performance for requisition completion by ticket type

2004 Lead time performance (# days) by ticket type	Average	Standard Deviation	Coefficient of Variation	MIN	MAX	Total #
Stock days	26.0	43.3	1.67	0	302	63
SBF days	16.6	9.9	0.60	3	43	21
SOO days	78.5	46.1	0.59	7	248	188
Structural days	86.2	71.1	0.82	4	282	36
Non-Stock days	60.3	42.1	0.70	2	294	83
Rush days	25.4	42.6	1.68	0	204	43
Graphic days	41.3	33.3	0.81	2	171	109
All Shipments – All tickets	73.1	54.7	0.75	0	302	401
Overall Requisition days (non-rush)	82.3	66.5	0.81	0	302	172

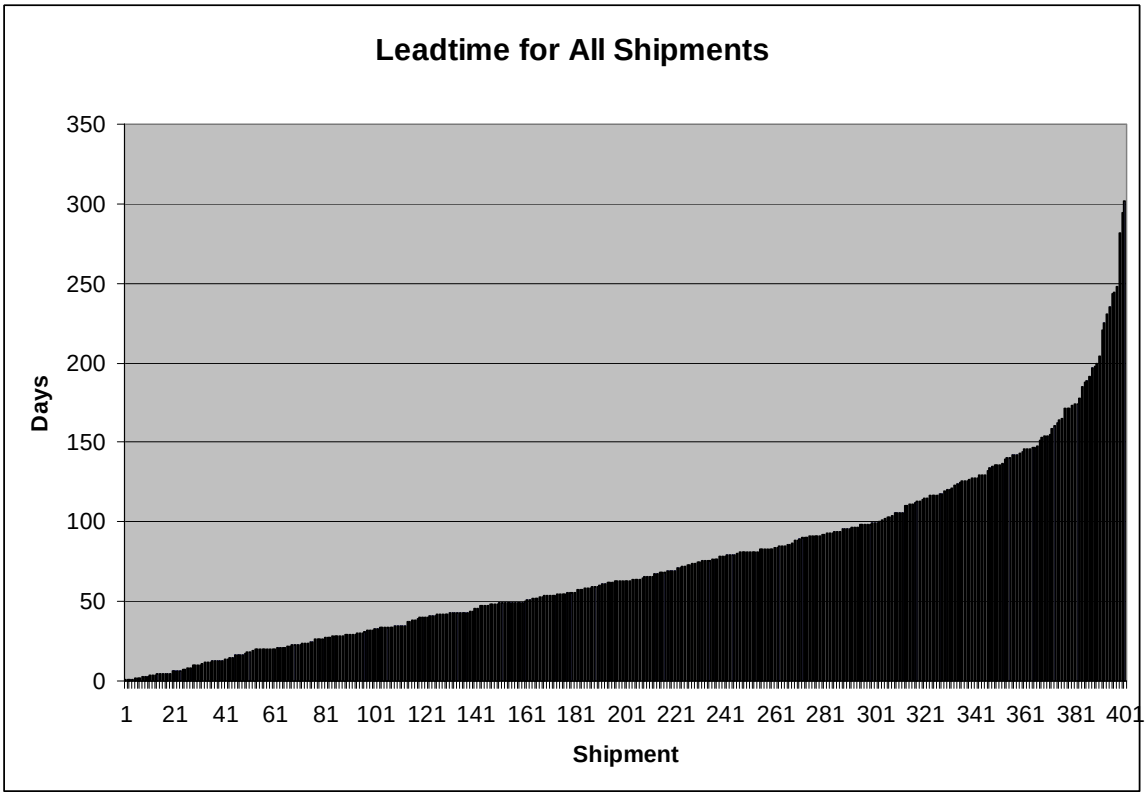


Figure 1 – 2004 Lead Time Distribution for All Shipments (days – for 401 samples)

4.2 Detailed process analysis (Value Stream Analysis)

This task entailed the development of detailed value stream maps for each of the three main sign product families (Silk Screen, White on Green and Structural). The maps represent the flow of an average sign requisition (148 signs = 138 Silk Screen + 8 White on Green + 2 Structural) from the District order to District receipt of the finished sign. The maps contain the information flow, material flow, processing times, and inventory levels for all aspects of the requisition Value Stream. Table 3 summarizes the various time components of the different value streams. Figures 2-4 are the Current-State Value Stream maps for each product family.

Table 3 - Current Value Stream Analysis (per requisition)

Silk Screen	Minutes	Days
Office Processing Time	3364	7.0
Office Total Time	8644	18.0
Shop Floor Processing Time	491	1.0
Shop Floor Total Time	2411	5.1
Shop Floor Processing Time (including Screen Template)	616	1.3
Shop Floor Total Time (including Screen Template)	3016	6.3
Overall Silk Screen Time	11055	23.0
Overall Silk Screen Time (including Screen Template)	11660	24.3
White on Green	Minutes	Days
Office Processing Time	3364	7.0
Office Total Time	8644	18.0
Shop Floor Processing Time	100	0.2
Shop Floor Total Time	2020	4.2
Overall White on Green Time	10664	22.2
Structural	Minutes	Days
Office Processing Time	3364	7.0
Office Total Time	8644	18.0
Shop Floor Processing Time	2019	4.2
Shop Floor Total Time	4899	10.2
Overall Structural Time	13543	28.2

Figure 2 - Current Silk Screen Signs Value Stream Map

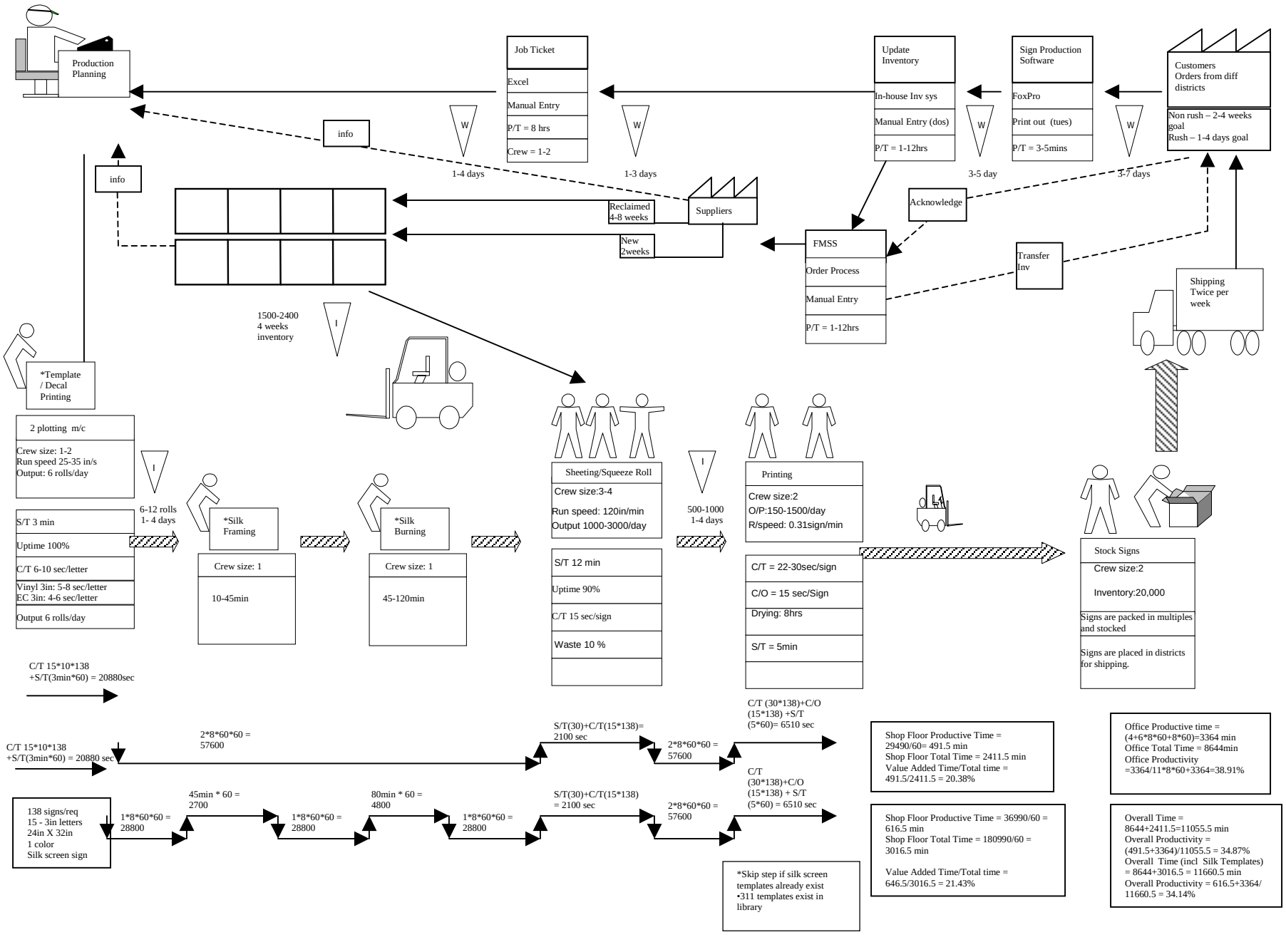


Figure 3 - Current White on Green Sign Value Stream Map

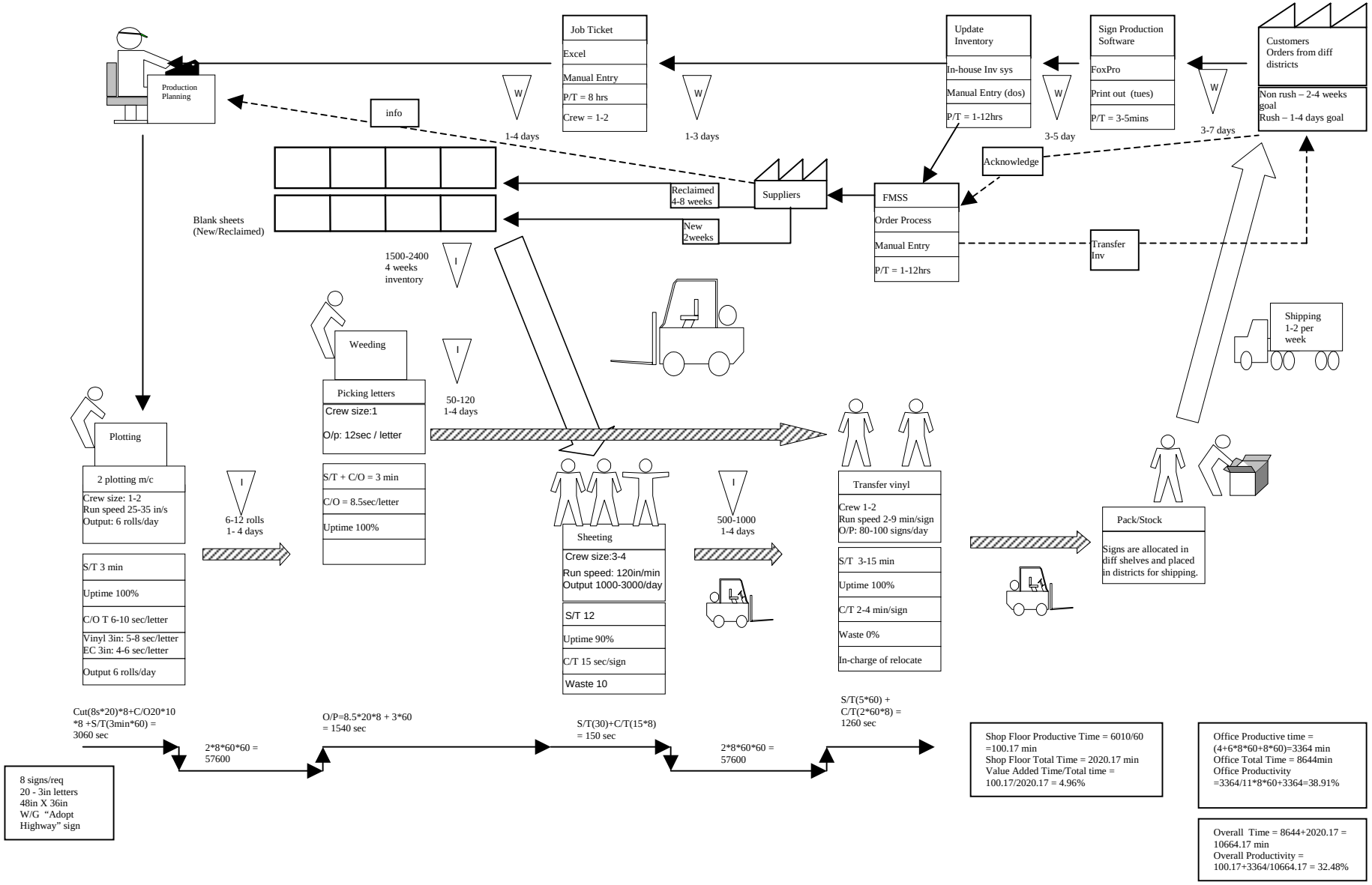
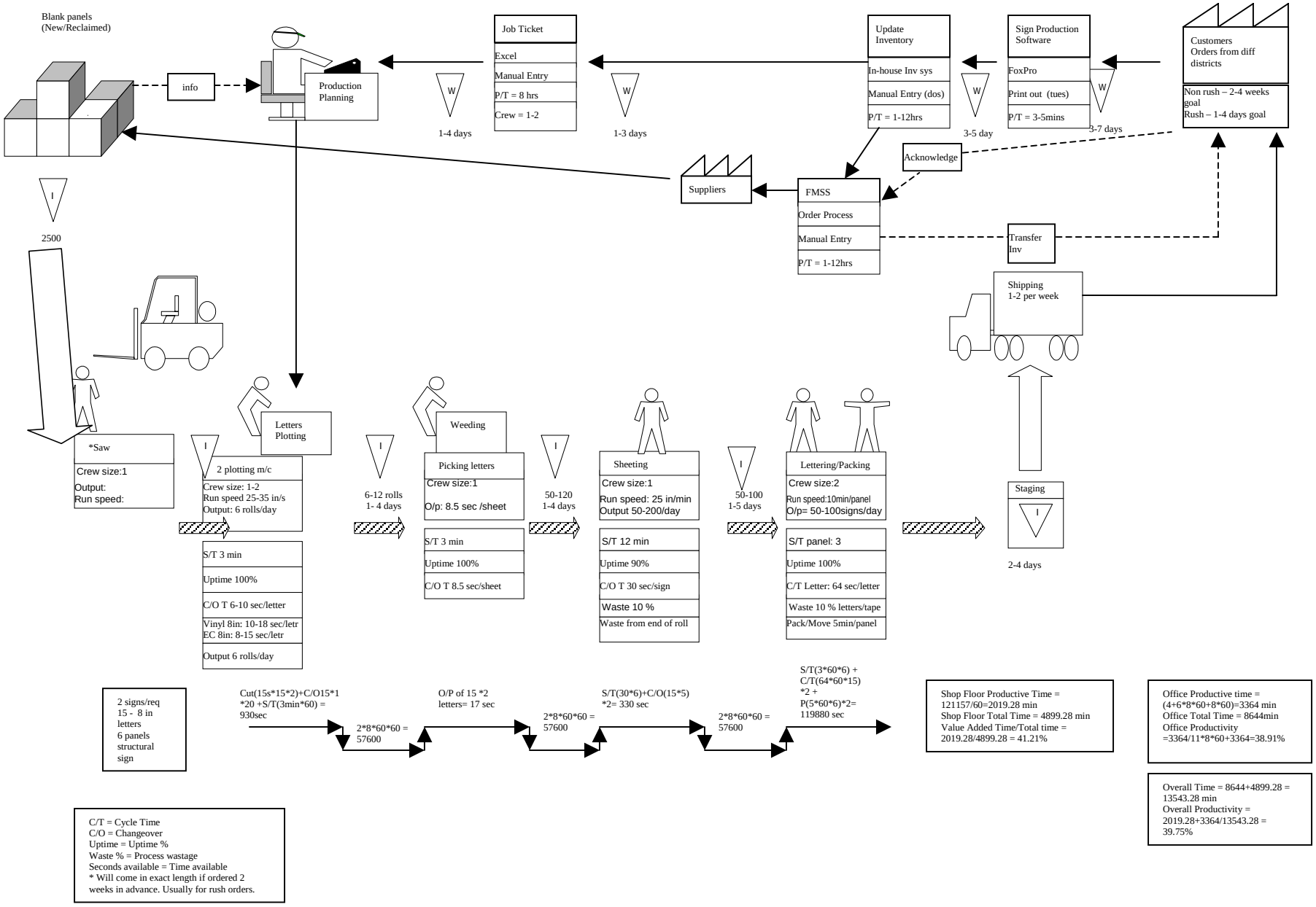


Figure 4 - Current Structural Sign Value Stream Map



4.3 Assessment of current production processes compared to state-of-the-art manufacturing practices.

A Lean Manufacturing assessment of the sign shop was performed to determine how it compares to state-of-the-art manufacturing facilities throughout the U.S. Table 4 presents the result of this assessment which is based on the "Rapid Plant Assessment" approach developed by Goodson, 2002. The Sign Shop scored a 36 out of a possible 121 (the national average is a score of 50). The score was based on the fact that the shop scored around average for factors related to customer satisfaction, safety, teamwork and equipment, but scored poorly for factors related to visual management, scheduling, inventory and integration. Further description of the factors used in the assessment can be found in the Appendix, together with the "20 Yes/No Questions" that also contribute to the overall plant assessment. It should be noted that the Sign Shop had 6 out of 20 yes answers, which is slightly above average for an overall rating of 36. This reflects the positive foundation for change which exists at the Sign Shop.

The next aspect of the sign shop assessment was to conduct a variability analysis of the Value Stream. Figures 5 to 7 and Tables 5 to 7 present the results of this analysis. In each Value Stream map the source of variability is noted. The Tables further describe the variability, note the location of the variability source and finally note the cause of the variability that needs to be addressed. Causes of variability listed in order of occurrence are: manpower availability, # orders, crew skill, production planning, and sign size, #different types of signs (setup), #finished signs, #different Districts' orders, supplier, and contract agent. The results of the variability analysis are key drivers of where system improvements should be targeted. This is most reliably shown when looking at the difference between the actual lead times for custom signs (41.3 to 86.2 days) and the Value Stream map lead times (22.1 to 24.3 days). This difference is the direct result of the causes of variability listed above.

Table 4 – Overall Lean Manufacturing Assessment Results

Rapid Plant Assessment - Ratings								
	Ratings →	Poor	Below Ave	Average	Above Ave	Excels	Best in Class	
No	**Measure ↓ Score →**	**1**	**3**	**5**	**7**	**9**	**11**	**Score**
1	Customer Satisfaction		X	X				**4**
2	Safety, environment, cleanliness, & order		X	X				**4**
3	Visual Management Deployment	X						**1**
4	Scheduling system		X					**3**
5	Product flow, space use & material movement means		X					**3**
6	Inventory & WIP Levels		X					**3**
7	People teamwork, skill level, & motivation			X				**5**
8	Equipment & tooling state & maintenance		X	X				**4**
9	Ability to Manage Complexity & Variability		X					**3**
10	Supply Chain Integration		X					**3**
11	Quality System Deployment		X					**3**
	Totals	1	7.5	2.5				**36**

Score of 36 out of 121, average for companies is 55 (Ref: R.E. Goodson, "Read a Plant Fast", Harvard Business Review, p. 105-113, May 2002).

Figure 5 - Current Silk Screen Sign Value Stream Map - Variability

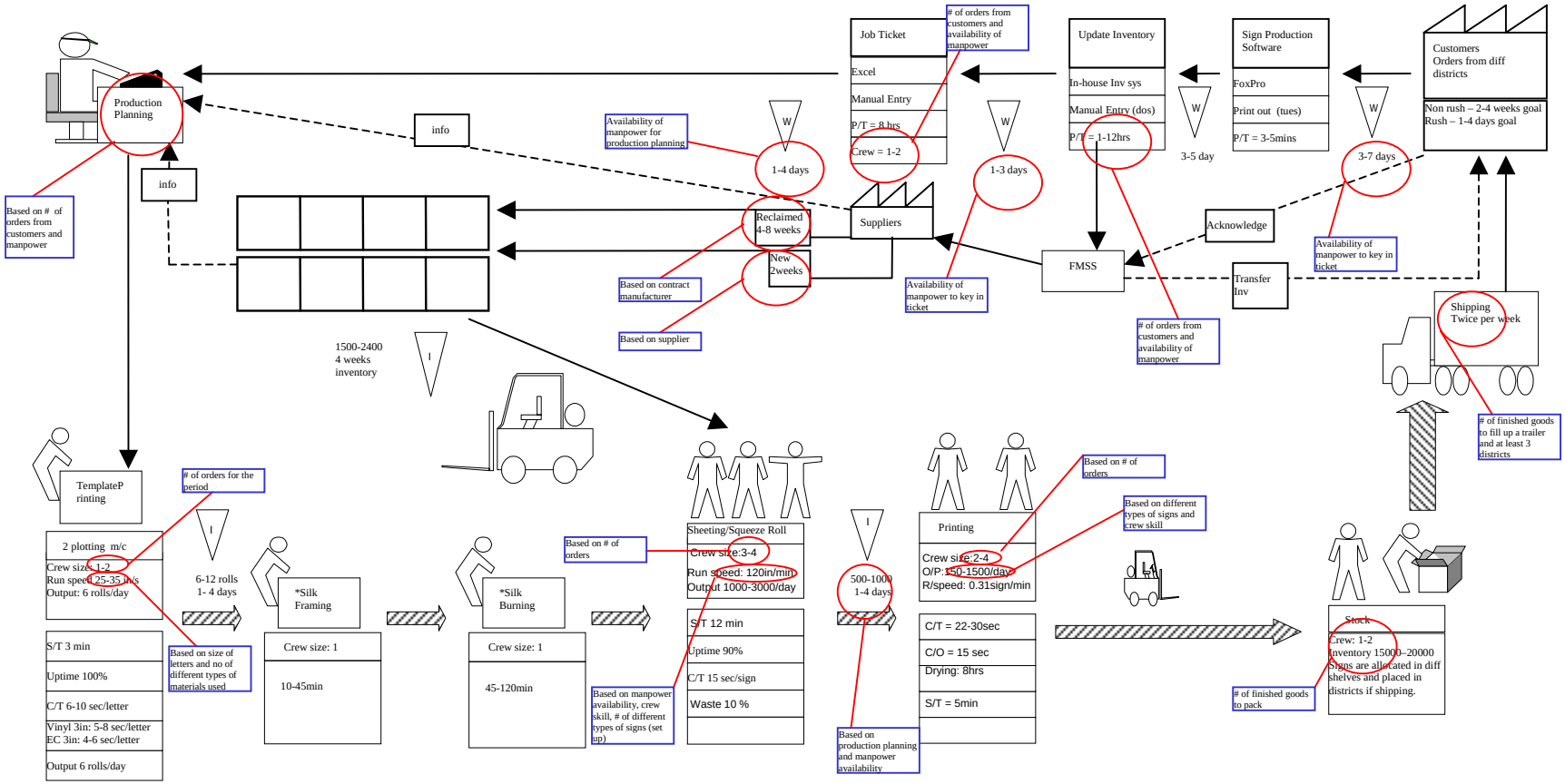


Table 5 - Cycle Time Variability for Silk Screen Signs

	Description of variability	Location	Cause of variability
1	Waiting time	Waiting time between customer orders and Sign production software	manpower availability
2	Process time and crew size	Update inventory	# orders, manpower availability
3	Waiting time	Waiting time between update inventory and job ticket	manpower availability
4	Crew Size	Job ticket	# orders, manpower availability
5	Production Planning	Production Planning	# orders, manpower availability
6	Supply	Blanks	supplier, contract agent
7	Crew size	Plotting	# orders
8	Run speed	Plotting	sign size, # different types of signs (setup)
9	Waiting time	After weeding	production planning, manpower availability
10	Crew size	Squeeze roll	# orders
11	Run speed	Squeeze roll	manpower availability, crew skill, # different types of signs (setup)
12	Waiting time	After squeeze roll	production planning, manpower availability
13	Crew size	Silk screen printing	# orders
14	Run speed	Silk Screen printing	# different types of signs (setup), crew skill
15	Crew size	Stock	# finished signs
16	Shipping time	Shipping	# finished signs, # different districts orders

Figure 6 - Current White on Green Sign Value Stream Map - Variability

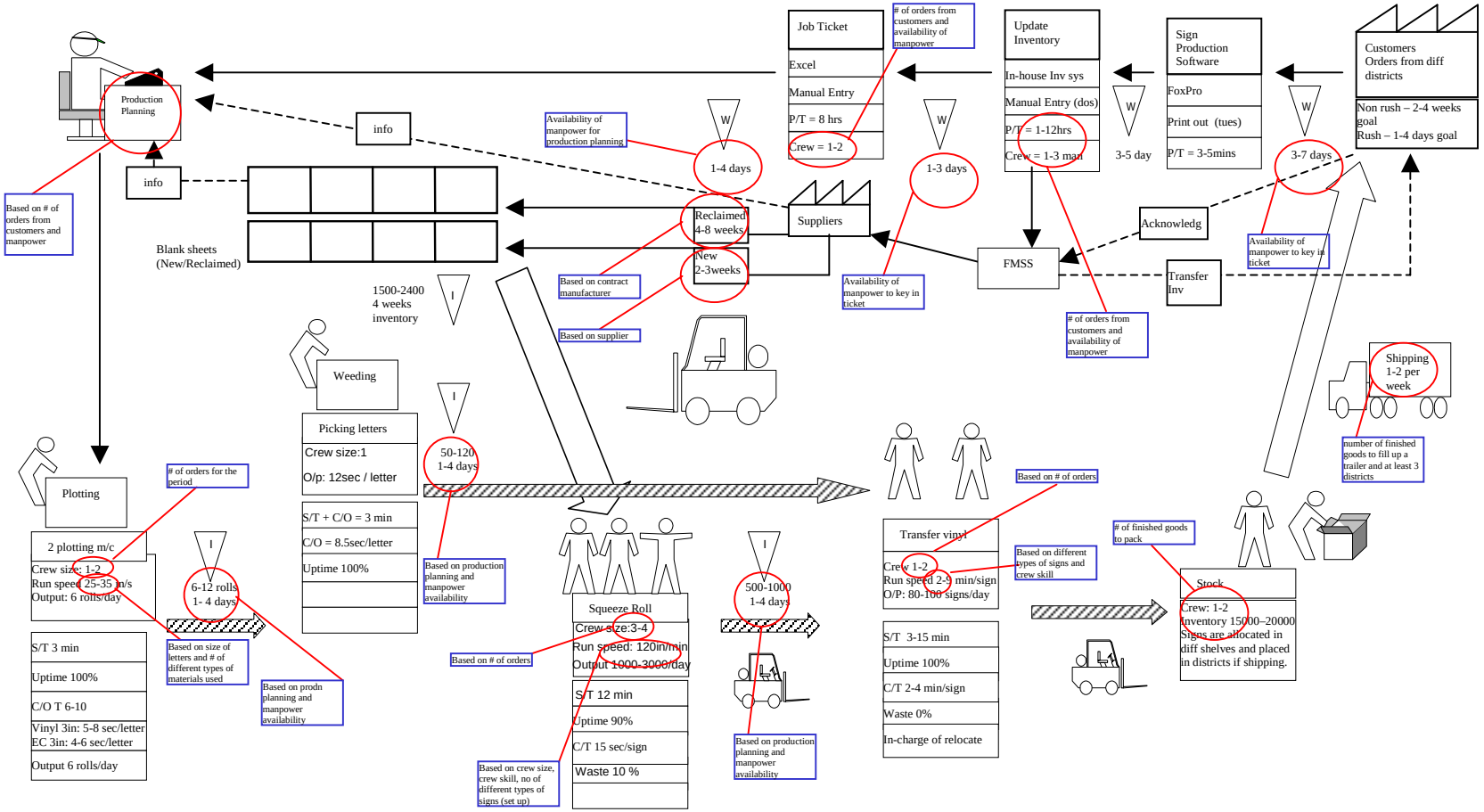


Table 6 - Cycle Time Variability for White on Green Signs

	Description of variability	Location	Cause of variability
1	Waiting time	Waiting time between customer orders and Sign production software	manpower availability
2	Process time and crew size	Update inventory	# orders, manpower availability
3	Waiting time	Waiting time between update inventory and job ticket	manpower availability
4	Crew Size	Job ticket	# orders, manpower availability
5	Production Planning	Production Planning	# orders, manpower availability
6	Supply	Blanks	supplier, contract agent
7	Crew size	Plotting	# orders
8	Run speed	Plotting	sign size, # different types of signs (setup)
9	Waiting time	After weeding	production planning, manpower availability
10	Crew size	Squeeze roll	# orders
11	Run speed	Squeeze roll	manpower availability, crew skill, # different types of sign (setup)
12	Waiting time	After squeeze roll	production planning, manpower availability
13	Crew size	Transfer vinyl	# orders
14	Run speed	Transfer vinyl	# different types of signs (setup), crew skill
15	Crew size	Stock	# finished signs
16	Shipping time	Shipping	# finished signs, # different districts orders

Figure 7 - Current Structural Sign Value Stream Map - Variability