Screen Printing Scheduling Methodology

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by

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Abstract

As the shift towards offshore business within the screen printing industry increases, American businesses must find a way to remain competitive. Due to manufacturing costs and regulation it is impossible for Americans to compete with the low per unit cost of foreign suppliers. By decreasing the time to market, American businesses will be able to remain competitive and recover lost business. In order to achieve this, a flexible scheduling model must be developed in order to increase throughput of a production process. This model serves to account for variables and variances that occur within the screen printing process, allowing for effective continuation of production.

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Screen Printing Scheduling Methodology

Chapter 1

In recent years the screen printing industry has experienced a continuous rise in the move towards offshore business. Due to low operating costs, foreign companies are able to offer a low per unit price, relative to domestic producers, to American businesses wanting to cut costs in an uncertain economy. Due to labor laws and regulations, competing American businesses are unable to contend with foreign pricing. The shift to offshore is leaving many of these businesses unable to survive in a competitive environment. In order to exist in the current business climate screen printing businesses must remain competitive by offering customers benefits other than that of price per unit.

Customers look for three elements when purchasing a product: cost, quality, and service. The general belief is that two of the three can be achieved at any one time. To remain competitive with foreign business, American businesses can offer the benefits of quality, and service, by decreasing the time to market. If American businesses are unable to compete in price, quality and time to market are alternatives that will allow them to retain customers. When purchasing from an offshore source, there is often a long lag time between purchasing and receiving the finished product. The initial cost of the product is low. However, long deliveries and corrections can be inconvenient. By offering quicker time to market and high quality product, businesses will be able to fulfill the needs of the customer.

This study answers the question: How can a screen printing business increase throughput and reduce time to market in order to remain competitive with foreign business? Research for this study was conducted at Coudray Serigraphics in San Luis Obispo, Calif. under the supervision of industry leader Mark Coudray. In order to increase throughput and reduce time to market, one must alter the production scheduling methodology. The traditional method of scheduling has mainly used the Gantt Chart System. The Gantt Chart is a visual reporting device used to convey a project or a production process schedule. The Gantt chart lays out the succession of events in a visual manner and allows for the monitoring of individual activities within a project according to a specified plan. The Gantt chart is based on an ideal production situation. Once something goes wrong with the schedule, everything is thrown off according to the Theory of Constraints. Due to related rates, once something happens, there is a "domino effect" throughout the rest of the schedule for the entire day, making it nearly impossible to recover from the incident. Using the Gantt method leaves a schedule vulnerable to potential threats.

Traditional scheduling methods use a "Rear View Mirror" method of scheduling. Projects and production plans are based on previous projects. With this type of hind-sight scheduling, managers are looking to the past in order to plan for the future. This history-based method of scheduling prepares a process for what has happened, as opposed to what could or will happen. In reality, it is necessary to anticipate according to trend lines, rather than base decisions on previous occurrences.

Traditional scheduling methods lend themselves to a slow reaction time. After something has occurred within a process, it is reported through the "grapevine" and eventually reaches upper management. At this point, the problem is assessed and necessary action is taken in order to correct whatever it was that went wrong or needed improving. This process of recognizing and addressing an issue could take days, weeks, or in some cases months to correct. At this rate, the problem is not addressed in a timely manner, thus reducing the effectiveness of the report. Once a problem is addressed, it is too late. In an ever changing business environment, reaction time is key to maximizing the efficiency and effectiveness of a process. The Forward Thinking Scheduling Model is a lean, flexible scheduling method based on known inefficiencies and independent and dependent variables. The method is an anticipatory method of scheduling that accounts for the dynamic nature of processes and allows for the maintenance of job flow in the event of an occurrence that would normally throw a production schedule off.

William Edwards Deming stated that in order to control a process, it is key to move all variables possible to the front of that process. Once variables are addressed at the front end, everything else will fall in line. With regard to screen-printing for example, this may mean addressing problems such as file format issues and substrate issues before press, that way, the only variables left are on-press issues natural to the process.

The scheduling method is a flexible activity based method of job scheduling. This means the model is flexible enough to account for any situation that arises. Regular job flow is sequential having one job after another, and in some cases parallel having multiple jobs running at the same time in order to maximize effectiveness of equipment and boost OEE (overall equipment effectiveness). In this model, as soon as something goes wrong, the process switches to flexible scheduling in order to account for the situation and maintain job flow. This calls for the building of buffers into a process to efficiently substitute another job in the place of the stopped or pending job. By moving a stopped job into a built in buffer, jobs waiting in line can then move in taking the place of the stopped job, maintaining job flow, and avoiding a possible choke point. With regard to screen-printing, this may mean keeping six colors on a fourteen-color press as insurance. In the event of a screen break, two three-color jobs, or one five color job can then move onto the press and begin production. This allows for the necessary maintenance on the downed job without stopping the press at all.

The method also calls for a Future-Casting production process. This is the ability to identify warning signs that could lead to potential problems. By learning the underlying science to a process, one will be able to identify irregularities and indicators that a process is going to go out of variance. Once a process goes out of variance, it is likely that something will occur to halt production. By recognizing and preventing these potential problems, one insures a high probability of success for the particular process.

From an accounting standpoint, an activity based scheduling method may enable a business to increase throughput and profit through costing based on activities rather than best-guess hourly rates. By increasing throughput, the break even day can be moved earlier and earlier within a month. Instead of reaching the break-even point at day 21, it may now be acquired at day 19. After the break even day has been reached, everything else flows to the bottom line. This means an increase in profit and capital.

The purpose of this study is to establish a forward thinking, flexible scheduling model that will facilitate the increase in throughput of a production process and decrease time to market. By creating a scheduling model that is able to withstand potential threats, a production process will become more efficient. Businesses will be able to accommodate deadlines of customers while delivering a quality product. In doing this, we believe businesses will be able to retain customers who would otherwise look to offshore business.

Screen Printing Scheduling Methodology

Chapter 2

> "Screen printing is arguably the most versatile of all printing processes. It can be used to print on a wide variety of substrates, including paper, paperboard, plastics, glass, metals, fabrics, and many other materials. including paper, plastics, glass, metals, nylon and cotton. Some common products from the screen printing industry include posters, labels, decals, signage, and all types of textiles and electronic circuit boards. The advantage of screen-printing over other print processes is that the press can print on substrates of any shape, thickness and size. A significant characteristic of screen printing is that a greater thickness of the ink can be applied to the substrate than is possible with other printing techniques. This allows for some very interesting effects that are not possible using other printing methods. Because of the simplicity of the application process, a wider range of inks and dyes are available for use in screen printing than for use in any other printing process" (PNEAC).

Screen printing has evolved into a form of printing that has many applications. "Everything from soda bottles, to T-shirts, to coffee cups, and cars are all screen printed" (Pedretti). Screen printing is a versatile printing process that has become a staple member of the graphic arts industry (Coudray).

> "Screen printing consists of three elements: the screen which is the image carrier; the squeegee; and ink. The screen printing process uses a porous mesh stretched tightly over a frame made of wood or metal. Proper tension is essential to accurate color registration. The mesh is made of porous fabric or stainless steel mesh. A stencil is produced on the

> screen either manually or photo-chemically. The stencil defines the image to be printed in other printing technologies this would be referred to as the image plate "(PNEAC).
>
> "Screen printing ink is applied to the substrate by placing the screen over the material. Ink with a paint-like consistency is placed onto the top of the screen. Ink is then forced through the fine mesh openings using a squeegee that is drawn across the screen, applying pressure thereby forcing the ink through the open areas of the screen. Ink will pass through only in areas where no stencil is applied, thus forming an image on the printing substrate. The diameter of the threads and the thread count of the mesh will determine how much ink is deposited onto the substrates" (PNEAC).
>
> "Many factors such as composition, size and form, angle, pressure, and speed of the blade (squeegee) determine the quality of the impression made by the squeegee. At one time most blades were made from rubber which, however, is prone to wear and edge nicks and has a tendency to warp and distort. While blades continue to be made from rubbers such as neoprene, most are now made from polyurethane which can produce as many as 25,000 impressions without significant degradation of the image" (PNEAC).

"If the item was printed on a manual or automatic screen press the printed product will be placed on a conveyor belt which carries the item into the drying oven or through the UV curing system. Rotary screen presses feed the material through the drying or curing system automatically. Air drying of certain inks, though rare in the industry, is still sometimes utilized. The rate of screen printing production was once dictated by the drying rate of the screen print inks. Do to improvements and innovations the production rate has greatly increased. Some specific innovations which affected the production rate and has also increased screen press popularity include:

1. Development of automatic presses versus hand operated presses which have comparatively slow production times.
2. Improved drying systems which significantly improves production rate.
3. Development and improvement of U.V. curable ink technologies
4. Development of the rotary screen press which allows continuous operation of the press. This is one of the more recent technology developments" (PNEAC).

The Gantt Chart was developed by Henry Gantt between 1910-1915. A Gantt chart is a graphical representation of the duration of tasks against the progression of time. Gantt Chart is a scheduling tool used to display the status of a project's tasks. "A Gantt chart shows each task's duration as a horizontal line. The ends of the lines correspond to the task's start and end dates" (Georgetown). There are some limitations when using the Gantt Chart. "Most of the Gantt charts are analytically thin, too simple, and lack substantive detail. The charts should be more intense. At a minimum, the charts should be annotated--for example, with to-do lists at particular points on the grid. Costs might also be included in appropriate cells of the table" (Tufte). Gantt Charts "encourages a one-step approach to planning. As a result of the presentation capabilities of modern planning packages, the visual quality of color charts means that they gain an implicit credibility. This can result in staff being unwilling to challenge the charts, and so they gain a momentum all of their own. Thirdly, they encourage the project manager to over-control the project rather than devolve the responsibility for the time-plan to team members" (Maylor). In most production processes there are potential constraints that can occur. If one of the screens brakes during printing it will slow down the whole process. Everything comes to a halt until the problem is fixed. This will inevitably change when other jobs will be produced. The Gantt chart leaves you no buffers or flexibility to not only fix what's going on, but at the same time continue on with a different job while the other one is being fixed (Coudray).

"A 'related rates' problem is a problem which involves at least two changing quantities and asks you to figure out the rate at which one is changing given sufficient information on all of the others. For example, as two vehicles drive in different directions we should be able to deduce the speed at which they are separating if we know the individual speeds and directions" (Bogley). Mark Coudray, owner and operator of Coudray Serigraphics in San Luis Obispo, Calif., describes the screen printing process as involving a related rates based system. In the production process, operations are sequential; therefore anything that occurs at one stage in the process will inadvertently affect all following stages (Coudray). As soon as an event occurs at the beginning of the production schedule for the day, the event has a domino effect on the rest of the schedule, therefore throwing off the initial plan. When this happens, the rest of the day is spent playing "catch up" in order to recover from the event (Coudray).

In order to illustrate the effects of related rates, the screen printing process can be described using a traffic flow model. The production process is similar to that of the traffic flow on a freeway or highway. As cars are traveling at a constant speed, all units are moving in relation to one another. When an event occurs, in this case a traffic accident, there is a domino effect throughout the rest of the freeway. Cars in immediate proximity of the accident must slow to a stop in order to safely pass the accident. This slowing of the cars at the accident in turn causes the cars behind them to slow and so on. An accident that occurs on the freeway affects the traffic flow a mile behind it due to related rates. Just like the production process, it takes a long time to move the accident out of the traffic flow and return to maximum speed (Coudray).

The foundation for the scheduling methodology is the theory of constraints. In his 1986 book entitled *The Goal*, Eliyahu Goldratt first introduced the theory of constraints that was aimed at helping organizations effectively achieve their goals (Goldratt). According to Robert Stein in his book titled *The Theory of Constraints,* “The TOC, which is based on the natural laws that govern every environment, seek to determine the underlying cause(s) of problems and to find the best solutions” (Stein, 1). Any manageable system is limited by a small number of constraints, and there is always at least one constraint. The TOC process seeks to identify the constraint, and restructure the organization around it in order to facilitate the best outcome throughout the use of a five focusing steps (Dettmer, 14).

“Constraint” is defined as follows: one that restricts, limits, or regulates; the state of being restricted or confined within prescribed bounds (The American Heritage Dictionary of the English Language). In order to identify the constraints within a process, Goldratt has developed five sequential steps to concentrate improvement efforts on the component that is capable of producing the most positive impact on the system. The five focusing steps include identifying the system constraint, deciding how to exploit the constraint, subordinating everything else, elevating the constraint, and finally repeating the process by looking for the next constraint (Dettmer, 14).

Identify the system constraint. By identifying the weakest link in a system one can focus improvement efforts in order to remedy the constraint. The weak link can be a physical attribute, or a flaw in policy. By identifying the type of constraint, the proper measures can be implemented (Dettmer, 14). “In any chain of events there can be only one weakest link, and if improvement is to occur only the weakest link needs to be strengthened” (Stein, 8).

The next step is to decide how to exploit the constraint. Changes and upgrades to a system can be costly. Without committing to such expenses, one must exhaust a constraining component of its complete capability as it currently exists (Dettmer, 14). In this stage it is important to decide how best to progress toward the goal of a system within the current constraints (McMullen, 44). Process planning may include outlining a specific plan, or steps that best supports the goal.

Subordinate the constraint. After identifying the constraint and establishing a plan of action, the rest of the system is adjusted in order to accommodate the constraint and allow it to operate at maximum effectiveness (Dettmer, 14). This includes bringing other considerations in line with what has been established in steps one and two; identifying the constraint, and deciding how to exploit the constraint. By altering the system's policies, processes, and other resources, a support system is created that facilitates the successful operation of the constraint (McMullen, 44).

After implementing the previous steps, if the constraint is still constraining the system's performance, elevating the constraint becomes necessary. At this step in the process, the need to entertain the idea of major changes to the existing system surfaces. This may come in the form of reorganization, divestiture, capital improvements, or other substantial system modifications. Necessary action is taken in order to eliminate the constraint and can result in a considerable investment in time, energy, money, or other resources. At the completion of this step, the constraint has been broken (Dettmer, 14).

The last step in the focusing steps involves the principles of continuous improvement process. "Continuous improvement is an ongoing effort to improve products, services or processes. These efforts can seek "incremental" improvement over time or "breakthrough" improvement all at once" (ASQ). This process involves the constant evaluation of a process in order to maintain maximum effectiveness. After the breaking of the initial constraint, the cycle begins again in order to identify the next thing constraining performance (Dettmer, 14).

The ultimate goal of the TOC process is to increase the effectiveness of a process in order to increase throughput. Throughput is the money produced by a system. Throughput is not parts or production related; a part becomes throughput only when the customer is invoiced. By increasing the amount of throughput, a production process becomes more profitable (Woeppel, 6).

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Chapter 3

Several research methods were used including Elite and Specialized interviewing as well as descriptive research. "A procedure that requires asking precise, open-ended questions, but questions that are open to refinement as the research and interview continues" describes Elite and Specialized Interviewing (Levenson). It is important to remember, when conducting an Elite and Specialized interview, the type of people you are interviewing. Lewis A. Dexter noted that "people who perceive themselves to be important, such as professionals and executives, must be interviewed differently than the 'average person on the street' in maximizing the collection of useful information in applied research" (Levenson).

Elite and Specialized interviewing was conducted by contacting industry leader, Mark Coudray, of Coudray Serigraphics in San Luis Obispo, Calif. as well as Prof. Ken Macro of California Polytechnic State University in San Luis Obispo, Calif. The following questions were asked:

1. In what ways are scheduling models, e.g. Gantt Charts, beneficial?
2. How would "Theory of Constraints" be a beneficial scheduling tool?
3. How beneficial is it to incorporate buffers into a production process in order to account for errors?
4. How important is it for U.S. companies to lower time-to-market in order to stay competitive with foreign companies?
5. In what ways is an activity based scheduling model a good alternative for screen printing?

Another research method used was descriptive research. One of the goals of the project was to develop a visual representation of the screen printing process in order to better understand where constraints may exist. "Descriptive research studies are designed to determine the nature of a situation as it exists at the time of the study. The aim is to describe, 'what exists' with respect to variables or conditions in a situation" (Levenson).

Descriptive research was used in order to gather relevant research data. A research grant through the company Imagine That!© was acquired. The research grant enables unlimited use of the ExtendSim software. The software was used to create the visual representation of the screen printing production process. Each step of the workflow was represented visually. The software modeled and simulated the screen printing process giving us an overview of how each part is performing. Measurements were taken as to how long the process will take, how many shirts the could be produced per hour and where possible constraints lie. Further examination of the model was done in order to organize and draw conclusions from the findings. The goal was to recognize the necessity and benefits of implementing a new scheduling model into the screen printing process. The aim was to observe the individual constraints and establish how they effect the process. Since the aim was to lower time-to-market, knowing which constraints slow down the process was essential to minimize time spent on each part of the process. For example, if a file was received that is not ready for print and has improper file preparation this causes a constraint in the process. By knowing where the variables lie in the problem and removing the variables we can speed up the printing process. By creating file preparation standards and guidelines customers can follow before sending the file for print. Hopefully, much less time is spent correcting files.

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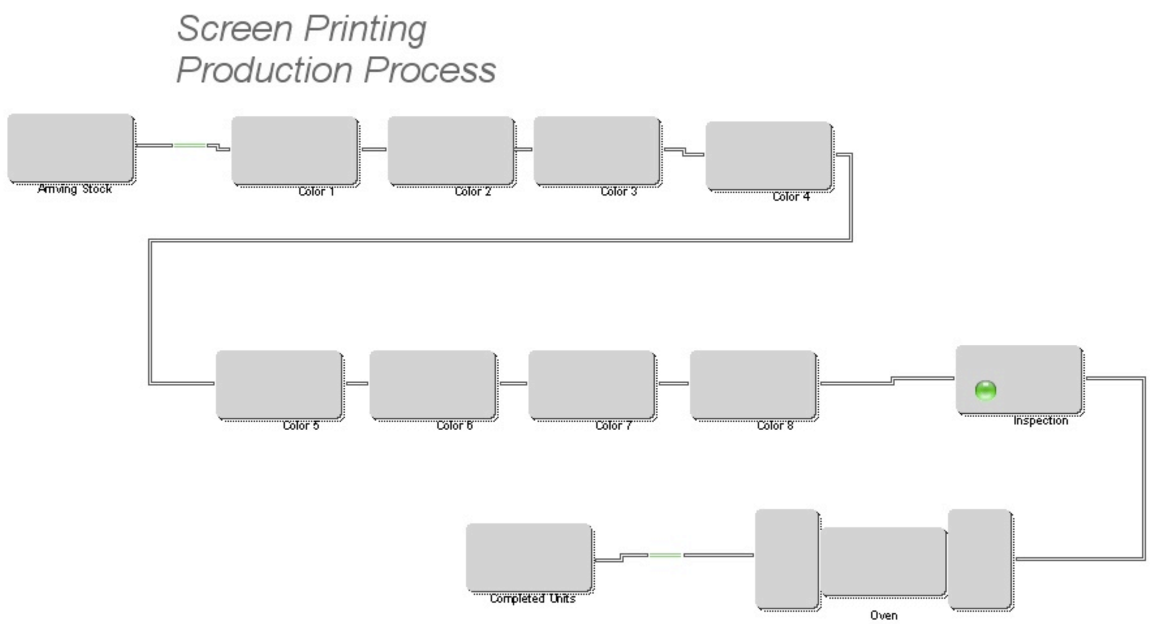
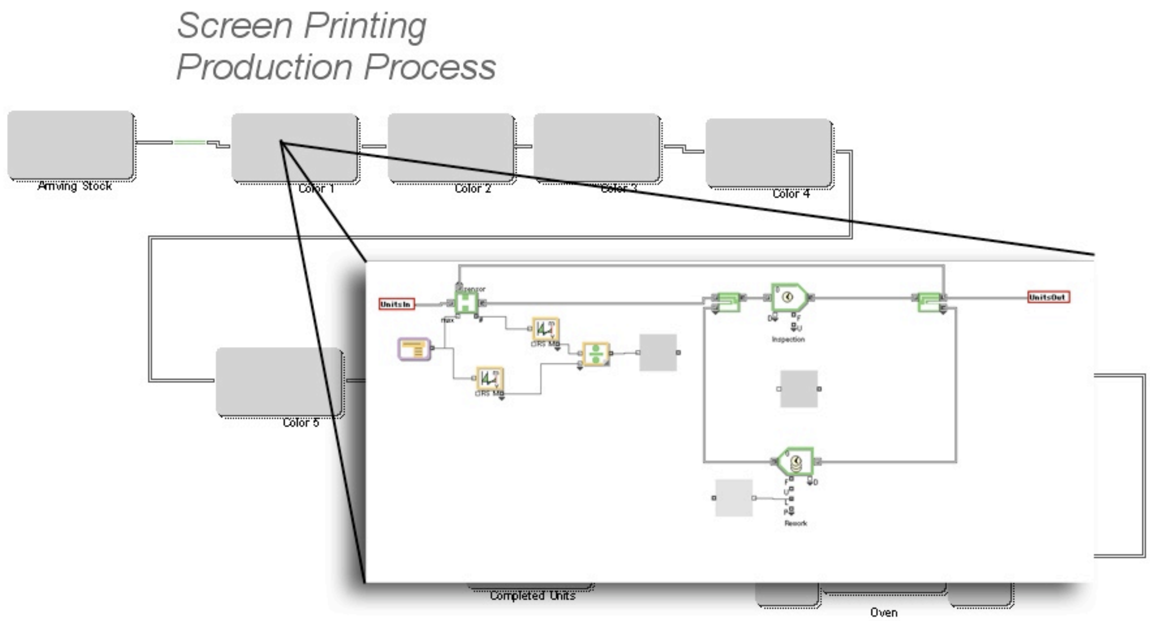
Chapter 4

In order to create a visual representation of the screen printing workflow the ExtendSim software was used. The software allowed for the creation of a visual model, representing each step in the production process. These steps included the arrival of stock, printing using an 8 color process, inspection of the units, drying of ink through an oven, and the delivery of finished units.



The model used was setup in "blocks". Each block represented a particular activity that occurred within the process. Within each main block or activity, there were other blocks that served to define the behavior of the main blocks.



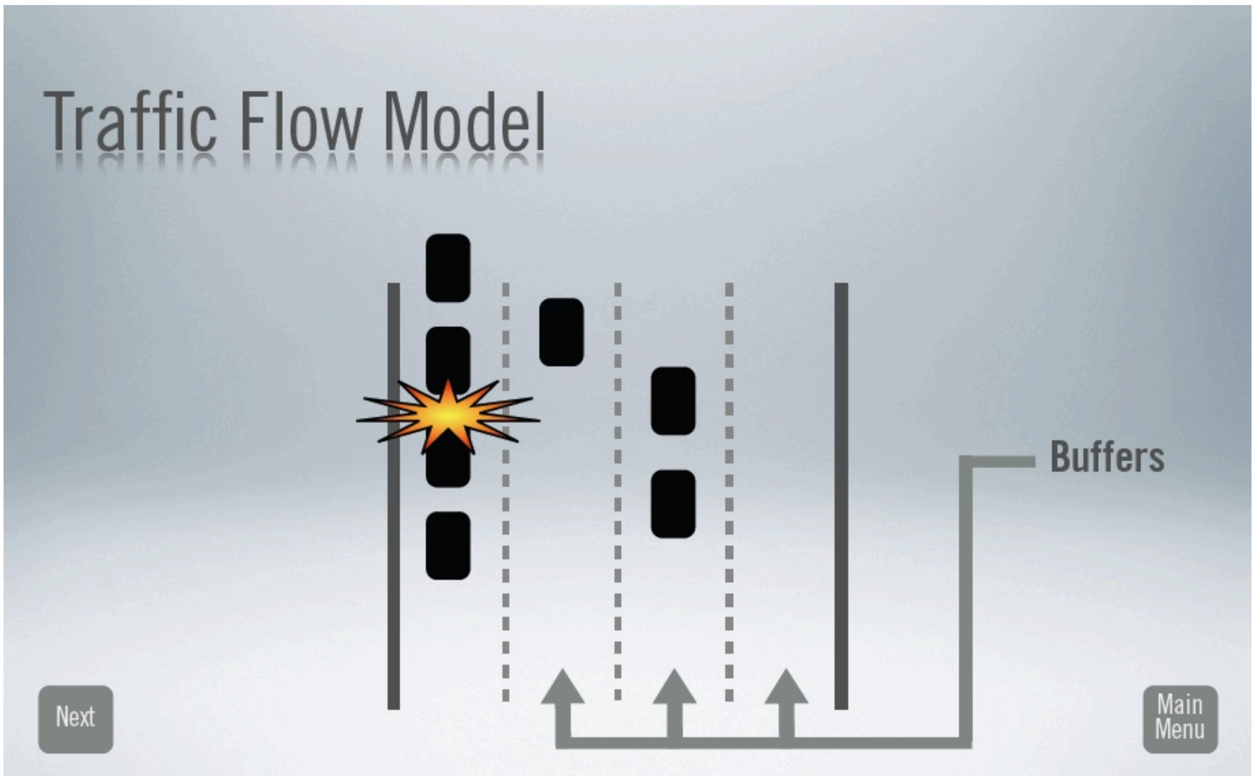
The screenshot illustrates the behavior of the "Color 1" activity. This represents the printing of one color on the press. Within this block there are other behavioral blocks that determine how the activity will behave. In this case There are a series of blocks that tell the program to spend a given amount of time performing the activity, as well as an event with a given probability that a variable will constrain the process and delay production. There is also an inspection unit that addresses the variable.

As the program runs, a visual representation of the process is displayed. From this, one is able to see each part of the workflow operate. Constraints become apparent and conclusions can be made from insight gathered from the program.

For Elite and Specialized Interviewing, Professor Ken Macro and Mark Coudray were interviewed. The questions asked were:

1. In what ways are scheduling models, e.g. Gantt Charts, beneficial?
2. How would "Theory of Constraints" be a beneficial scheduling tool?
3. How beneficial is it to incorporate buffers into a production process in order to account for errors?
4. How important is it for U.S. companies to lower time-to-market in order to stay competitive with foreign companies?
5. In what ways is an activity based scheduling model a good alternative for screen printing?

During the interviews both interviewees explained that Gantt Charts can be beneficial because it gives a basic visual idea of when each job is to be performed and how long they estimate to finish. They said it is a bar chart, more or less, that everyone can read and understand when a job needs to start and finish. Alternatives to the Gantt Chart and the benefits of incorporating buffers and Theory of Constraints into a scheduling model like the Gantt Chart were discussed. It seemed unanimous that a main problem with a scheduling model like the Gantt Chart is there is no room for error. Each job is scheduled one after another and has a fixed time of when it needs to be done. When a problem does occur the whole process is shut down and it inevitably causes a constraint halting jobs that are behind the current job. Coudray and Macro both agreed that this is a flaw in the scheduling model. Coudray mentioned it is important to understand where potential constraints lie in the process so hopefully you can avoid them or eliminate them early on in the process. Professor Macro agreed that implementing buffers into the process to allow for errors would be beneficial. It would give you room to move jobs and continue work without having to shut down the whole process losing time and money. Also discussed was the “traffic flow model” and how in a traffic jam every car has to slow down and eventually come to a stop. If there’s only one lane then traffic doesn’t flow again until the whole jam is cleared. If you have multiple lanes you can then shift cars around the jam and continue traffic flow. This allows you to avoid the constraint and gives you time to eliminate it. This same concept is what is desirable to implement in the screen printing process. Mark phrases it as “parallel processes”.



As the interviews came to a close both agreed that creating an activity based model in today’s screen printing industry is important. Most jobs are short-runs now and customers demand a short turn-around time. Creating a model with buffers so you can have parallel processes is a more efficient way to schedule jobs and helps eliminate potential constraints in the process. They understand the importance of bringing jobs back to the U.S. The way American companies can do that is to compete in time-to-market. The more efficient the process is the faster the product will be produced creating a competitive advantage with overseas manufactures.

Screen Printing Scheduling Methodology

Chapter 5

Conclusions and recommendations

After building a basic simulation of the screen printing process with a random amount of variables applied, variables affecting the process were exposed. A variable could be anything that would stall or hinder the process such as a screen break. The model gave a basic visualization of how much time it would take to produce a given amount of shirts with random occurrences of variables in the process. Implementing this simulation along with the enhanced scheduling model helps to make the screen printing process more efficient in handling the effects of variables within that process. Not only does the workflow have buffers to allow production to flow without shutting down completely, a framework has been developed for a working simulation model that visually shows how variables effect the process and when we can anticipate them. The new scheduling model including the simulation model can help screen printers develop a more "forward thinking" process that allows for more control and flexibility. The main goal with this project was to create a forward thinking model that lowers the time-to-market and thus helping American printers become more competitive with foreign competition.

After receiving the grant from Imagine That©, the basics of how to use the tools and interface were learned. After a couple of months of using the program it became apparent that building a sophisticated, working model would take at least a year to build and refine. Given the narrow time slot to finish the project, the basic framework for the simulation was developed. The program is for an eight color press and when the simulation is running it provides a minute by minute rundown of how the process is performing with a random number of variables applied to the process. After finishing the project, recommendations were made to engage students in the Graphic Communications department in learning the software and the fundamentals of the forward-thinking scheduling model. The basic program that was started has a lot of potential to be more dynamic and give more real-time analysis. The intent is to pass on the simulation to the department in hopes that it will continue to be built on and refined. As the industry continues to change and everything is going from long runs to short runs the project is a step forward in making the printing process more efficient and timely. Learning the basics of the Theory of Constraints and the traffic flow model is highly recommended. After understanding the fundamentals of the scheduling model it is encouraged that students and staff use the model and build on it to make it even more functional. Further project extensions may include the real time quantification of data using the production model. Many modern printing presses are equipped with technology that allows for the feeding of information from the press into a spreadsheet. The data contained in the spreadsheet can then be used within the program to refine an accurate production model to a specific operation. Future projects along with this foundation model will serve to provide a valuable business tool for the screen printing industry. By implementing a forward thinking model along with visual representation software, printers will be able to remain competitive by improving their workflow and decreasing time to market.

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