ELECTRONIC KANBAN SYSTEM FOR RUBBER SEALS PRODUCTION

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Abstract

A key success for automotive suppliers relies on its on-time delivery and efficient manufacturing process. A case-study rubber seal manufacturer is using just in time (JIT) techniques, requiring efficient process flow with low wastes. However, the majority of the current processes still rely on workers' expertise that can lead to process errors. In 2011, 699 events of rubber supplying delays were found and 525 events or 75.11% of these delays are due to inappropriate ordering and management of the Kanban system in the rubber preparation process. The objective of this research is, therefore, to improve the rubber preparation process by developing a logical method to identify appropriate times for each step and designing information management for the Electronic Kanban System (E-Kanban) to be able to deliver effective and accurate signaling. This E-Kanban system must be able to automatically indicate when each step in the rubber preparation should start so that the rubbers are prepared and ready for the next moulding process by the time they are needed. We also design user interface for an effective use of the system in actual operation. After the developed E-Kanban system was implemented in the factory from July to October 2012, we found that the number of rubber supplying delays could be reduced to 86 events and only 11 events or 12.79% of these delays are from the rubber preparation process.

Keywords: Rubber seal manufacturing, Electronic Kanban, Rubber preparation, Just in time

1. INTRODUCTION

Rubber seals are used as essential parts in automotive industry, which is one of the most fast-growing industries in Thailand. Since the number of auto parts factories increases every year, the existing companies need continuous improvement to maintain their current customers and keep their competitive competency in the long run. In this paper, we present a design of Electronic Kanban System for the preparation process of rubber seal manufacturing

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in our case study factory, which is a leading rubber seals factory in Thailand. There are three main processes in producing rubber seals. Mixing process occurs in the first step where polymers, additives (both reinforcement and non-reinforcement), Vulcanizate, Surfactan, and other additives are mixed in a designed condition inside an internal mixer. The second step is rubber preparation. This preparation step consists of two sub processes: job sequencing and preparation. Job sequencing occurs when the main production department places a Kanban card in the storage as a signal that the work in process (WIP) rubbers are needed for the manufacturing process. After job sequencing, the mixed rubber in a sheet form, having the highest priority, is rolled in two-roll mill machines. The last step is the main production, i.e., the moulding process that creates finished rubber seals by pressing them into a moulding metal cavity. Figure 1 shows the main processes of the case study factory.

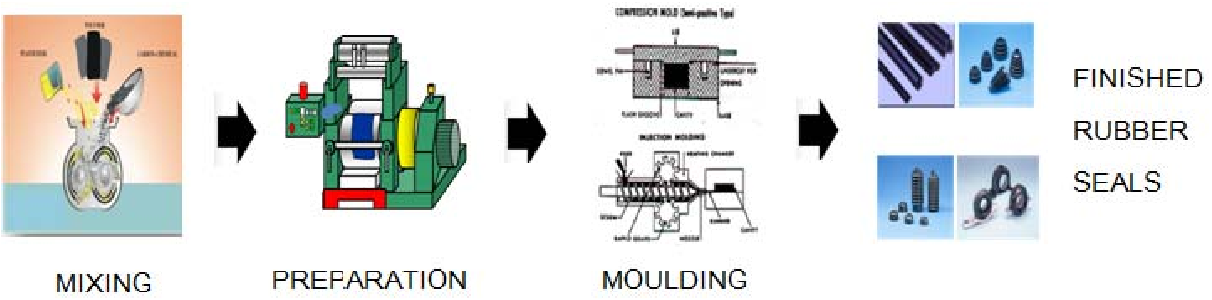


Figure 1: The main processes for rubber seals production.

A major policy used in this factory is just in time (JIT) production, i.e., producing only the necessary products in the necessary quantities at the necessary times. This policy utilizes a pull system for ordering, manufacturing and delivery control. The case study factory uses a classic manual Kanban system. Although it is able to trigger each step of production according to the pull system, Kanban card is only visible at the shop-floor and its transparency significantly decreases as the number of Kanban increases. It can also be ineffective if a card is lost. Similarly the Kanban management of the case study factory still relies on workers' expertise, which sometimes causes production errors. In 2011, there were 699 events of rubber supplying delays and 525 events or 75.11% of these delays are due to inappropriate ordering system and Kanban management in the rubber preparation process.

The main reason of rubber supplying delays in the rubber preparation process is ineffective pull system using manual Kanban cards that are sent either too early or too late. Some of the rubbers are prepared much in advance and are waiting for moulding, while the others are not ready in time for the moulding process, resulting unnecessary waiting time. From these observations, this paper proposes a logical method to identify appropriate times for each step in the preparation process and design information management for the Electronic Kanban System (E-Kanban) to be able to deliver effective and accurate production signaling. We also design user interface for an effective use of the system in actual operation.

2. LITERATURE REVIEW

Just in time production system was initially developed by the Toyota Motor Company of Japan. The production method of JIT system consists of smoothing of production, design of process and assignment of jobs (Reda 1987). This system aims to reduce work in process by utilizing Kanban for calling materials only when they are in needed for production (Al-Tahat and Mukattash 2006). It has been well accepted that JIT can result in reduced inventory costs, shorter lead times, and improved productivity (Ansari and Modarress 1990, Tracey et al. 1995, and Schonberger and Gilbert, 1983).

Several researches have proposed many approaches for JIT system. One of the most widely used policies is Kanban, defined as a material flow control mechanism that controls proper quantity and proper time of the production of goods. (Graves et al. 1995). Gupta et al. (1999) proposed a Flexible Kanban System (FKS) to handle random interruption in the production process. Several examples were carried out to compare the performances of this FKS policy with respect to the traditional JIT system and found this new system can outperform the traditional JIT system in all the cases considered. Tardif and Masseidvaag (2001) developed an adaptive pull system where the number of cards in the system was dynamically re-adjusted based on current inventory and backorder levels. Chan (2001) studied the effects of varying Kanban size on the performance of just-in-time (JIT) manufacturing systems. He found that for a single product, as the Kanban size increased, the fill rate decreased, while both the in-process inventory and the manufacturing lead time increased. For multi-products manufacture, he observed as the Kanban size increased, the fill rate increased with a decrease in the production lead time. A complete review of different variations of Kanban system can be found in Muris and Moacir (2010), where thirty two different Kanban systems were studied and classified according to six categories.

A traditional card based Kanban system has some limitations, e.g., inefficient work caused by card handling. For a large scaled production, the rapid pace of materials movement requires a large number of card movements as well. If there are human errors, the cards can be misplaced and cause serious production errors. E-Kanban is a variation to Kanban, where the physical card signal is replaced by electronic signals, known as E-Kanban system (Ansari and Modarress 1995). E-Kanban system can be used no matter the distance between the production department and it reduces the quantity of the company’s paperwork. Currently a number of major automotive companies in Thailand, such as Toyota Motor Thailand Co., Ltd., Thai Summit Auto Parts Industry Co.,Ltd., and Rubber Tech International Co,. Ltd., have applied the idea of E-Kanban in their production systems. While traditional Kanban has been widely explored in the literature, a fewer number of studies developed practical models for E-Kanban. Thus, this paper’s objective is to propose a design of E-Kanban system that can be effectively applied in automotive industries.

3. MODEL FORMULATION FOR E-KANBAN SIGNALING

One of the most important inputs of the E-Kanban system is the appropriate time for signals to start each step in the process. This section describes how to identify those inputs for the rubber preparation process of the case study factory.

The rubber preparation process starts once the prepared work in process (WIP) rubbers in the storage have been collected for the next process, i.e., rubber moulding. When the level of WIP rubbers in the storage reaches zero, the preparation process of the next batch of rubbers is triggered to be started so that they will be ready for the next moulding process (with no unnecessary waiting time). The rubbers in the storage are sequenced for their priorities and the batch with highest priority will be selected to be prepared via the two-roll mill machines. Then the work in process (WIP) rubbers are kept in the storage until they are picked up to be moulded in the next process. The steps in the preparation process can be shown in Figure 2.

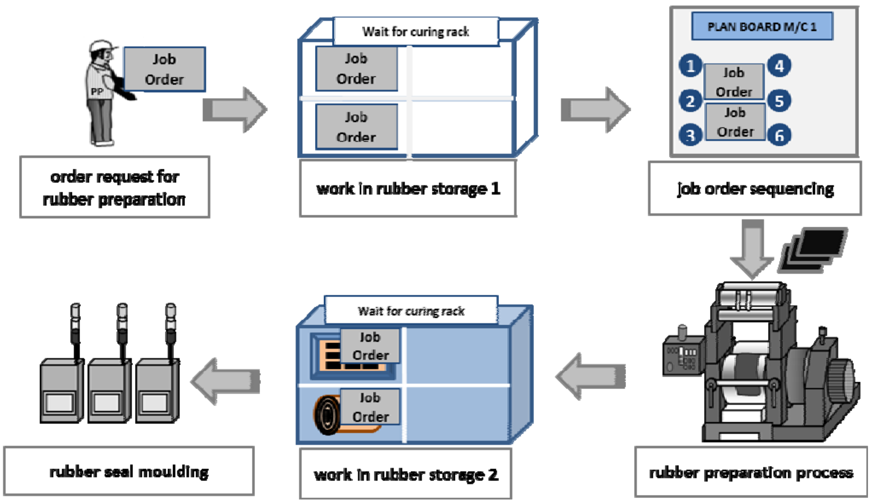


Figure 2: The flow of rubber seals preparation process

We present a method to identify the rubber preparation signaling periods that result in no unnecessary waiting time for the next moulding process.

Let

PT = the maximum total time in the rubber preparation process
(that WIP can be prepared rubbers in time for the next moulding process)
T_1 = Starting time for rubber sequencing
T_2 = Starting time for rubber preparation
T_3 = Finishing time for rubber preparation
(when WIP rubbers are kept in the storage)

R_1 = Amount of time required for rubber sequencing
R_2 = Amount of time required for rubber preparation
R_3 = Amount of time WIP rubbers should be kept in the storage (prior to the next moulding process)
X = Finishing time of the moulding process of the previous batch
CT = Cycle time of the moulding process
LCT = Cycle time of the moulding process of the previous batch

I. Identifying the maximum total time in the rubber preparation process (PT)

To prevent the unnecessary waiting time, the total time of the rubber preparation process for each batch must be less than the moulding cycle time of the previous batch. That is

$$PT \quad < \quad LCT. \qquad (1)$$

The moulding cycle time of 3,960 batches are collected from the factory during June 1 to June 30, 2011. Figure 3 shows the number of batches corresponding to different moulding cycle times. The minimum and the maximum moulding time are 4 and 12 hours, respectively.

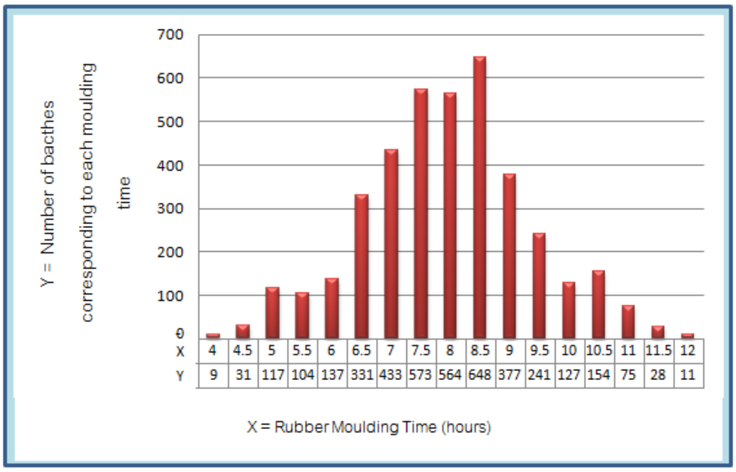


Figure 2: The number of batches corresponding to different moulding cycle times (recorded during June 1 to June 30, 2011)

Since the minimum moulding cycle time is 4 hours (min CT = 4 hours), we have

$$PT \quad < \quad 4 \quad \text{hours}. \qquad (2)$$

II. Identifying the finishing time for rubber preparation (T_3)

To prevent the delay of WIP rubbers for the moulding process, we seek the appropriate duration of time that the WIP rubbers should be ready in the storage prior to the actual starting time of the moulding process. That is

$$T_3 \quad = \quad X - R_3\,. \qquad (3)$$

Even though the moulding time for each batch of rubbers can be calculated in advance, the actual time can be either shorter or longer. Figure 3 shows the time differences between the actual and the calculated moulding time observed from 3,960 batches. It is observed that the maximum time difference is between 30 to 40 minutes. Thus, if the allowance of the finishing time for rubber preparation is set to be 1 hour, it can provide required WIP rubbers with no waiting time for the next moulding process. That is

$$R_3 \quad = \quad 1 \text{ hours.} \qquad (4)$$

Therefore, the finishing time for rubber preparation (or the time that WIP rubbers should be ready at the storage) is 1 hour prior to the finishing time of the moulding process of the previous batch. That is

$$T_3 \quad = \quad X - 1. \qquad (5)$$

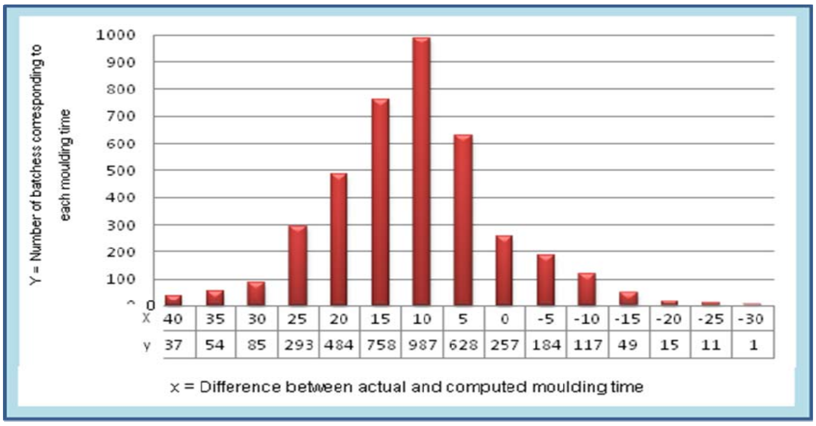


Figure 3: The number batches with their corresponding time differences between actual and the calculated moulding time (recorded during June 1 to June 30, 2011)

III. Identifying the Starting time for rubber preparation (T_2)

The stating time for rubber preparation must be occurred prior to the desired finishing time for rubber preparation. The allowance time in this step is necessary to prevent delays. We have

$$T_2 \quad = \quad T_3 - R_2. \qquad (6)$$

To identify the required preparation time, we have to consider all steps in the preparation process. The factory's standard time in this process is explored. Table 1 shows the standard time set by the factory for each step in the rubber preparation process.

Table 1: Standard time for each step in the preparation process

Steps	Time (mins)
Machine cleaning	10
Prepare materials	10
Rubber preparation	30
Quality Checking	10
Total	60

To verify the actual rubber preparation time to the standard time, we collected data from 3,960 batches produced during June 1 to June 30, 2011. Figure 4 shows the number of batches corresponding to their rubber preparation times. We found 99.72 percent of all data was less than 60 minutes and the maximum time was only 5 minutes greater than 1 hour. Therefore, setting the allowance of the starting time for rubber preparation to be 1 hour can provide acceptable result. That is

$$R_2 = 1 \text{ hour} . \tag{7}$$

From equation (5) $\quad T_3 = X - 1.$

Substituting T_3 and R_2 in (6) we have

$$T_2 = X - 2 . \tag{8}$$

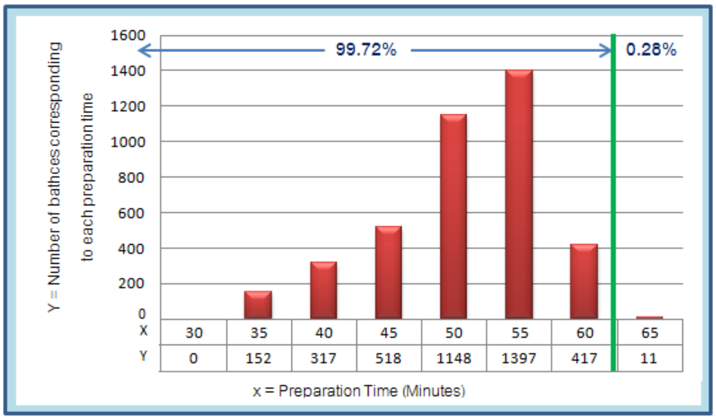


Figure 4: The number batches with their corresponding rubber preparation times

IV. Identifying the starting time for rubber sequencing (T_1)

To prevent WIP rubber delays due to inappropriate rubber sequencing times, we consider the allowance time needed in this process. The starting time for rubber sequencing should be set well prior to the starting time for rubber preparation. That is

$$T_1 = T_2 - R_1 . \tag{9}$$

Substituting T_2 from (8) in (9), we have

$$T_1 = (X - 2) - R_1 . \tag{10}$$

From equation (3) the maximum rubber preparation time such that there is no waiting for WIP rubbers should be less than 4 hours. That is

$$R_1 + R_2 + R_3 \quad < \quad 4\,.$$

Substituting R_2 and $R_{3,}$ we have

$$R_1 \quad < \quad 2\,. \tag{11}$$

From the record, the rubber sequencing takes approximately at most 1 hour. Setting R_1 to be 1 hour can satisfy (11). Thus, we have

$$T_1 \quad = \quad X - 3\,,$$

which means the starting time for rubber sequencing should be set as 3 hours prior to the finishing time of the previous batch's moulding process.

4. DESIGN OF INFORMATION MANAGEMENT FOR E-KANBAN

The pull system of the rubber preparation process starts when the workers collect WIP rubbers from the storage for the next moulding process. At this point, it will trigger as a signal that the next batch of WIP rubbers should be replaced in the storage. Figure 5 presents the flow of rubbers and the flow of Kanban signals in the rubber preparation process.

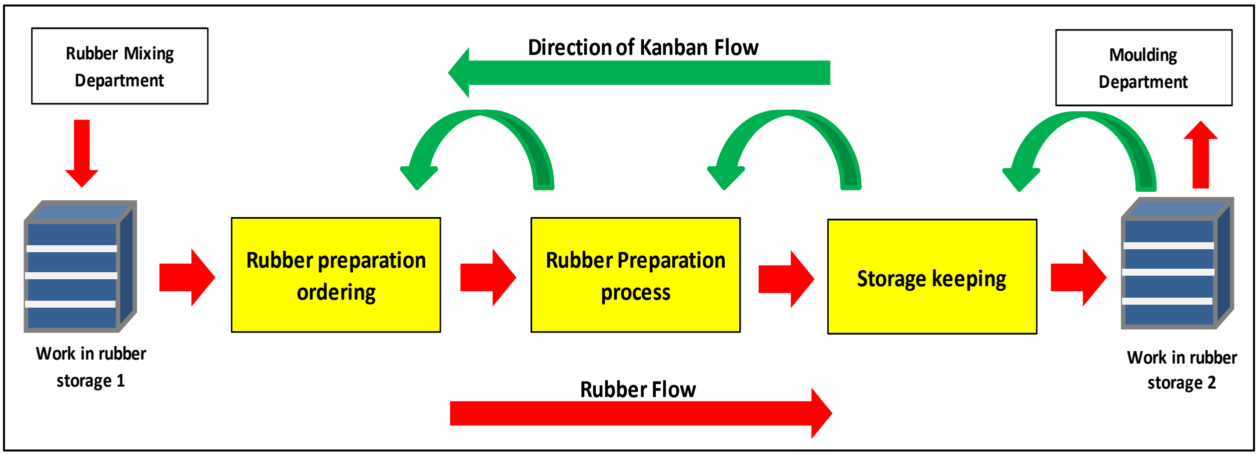


Figure 5: The flow of rubbers and the flow of Kanban signals

For the E-Kanban to be effectively implemented, we carefully study each step of the preparation process. This section describes data input, data output, reports from data processing, and related departments required for each step. Data flow diagram (DFD) is employed to show how a system's environmental entities, processes, and data are interconnected.

4.1 Context Diagram

This section presents the system context diagram, illustrating overall circumstances of the system's environment. This diagram shows the scope of the system considered in this paper (shown in Figure 6). The rubber preparation process for the E-Kanban is related to other departments, i.e., planning department, process design department, rubber mixing unit and rubber moulding unit.

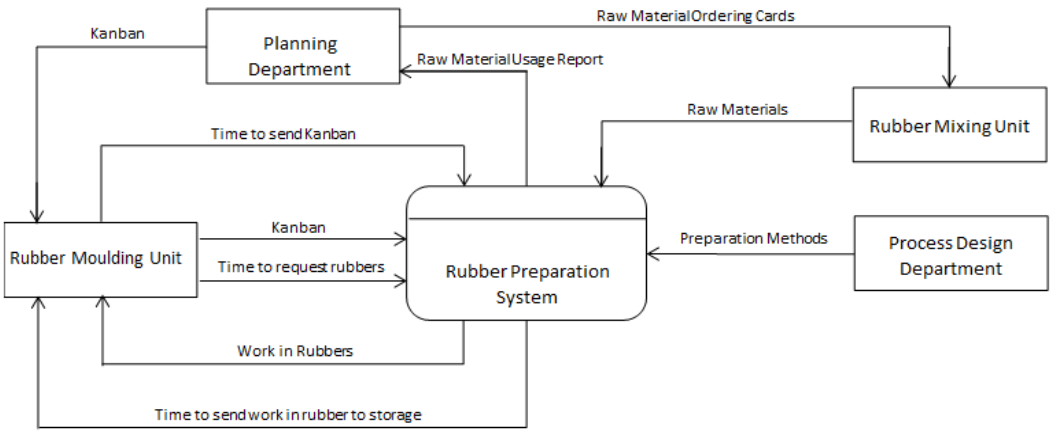


Figure 6: The system context diagram of the rubber preparation process

4.2 DFD Level 0

We use DFD Level 0 to represent the system's major processes at a high level of abstraction. Figure 7 shows the DFD level 0 of the rubber preparation process which consists of two parts: processing design department and production results displays.

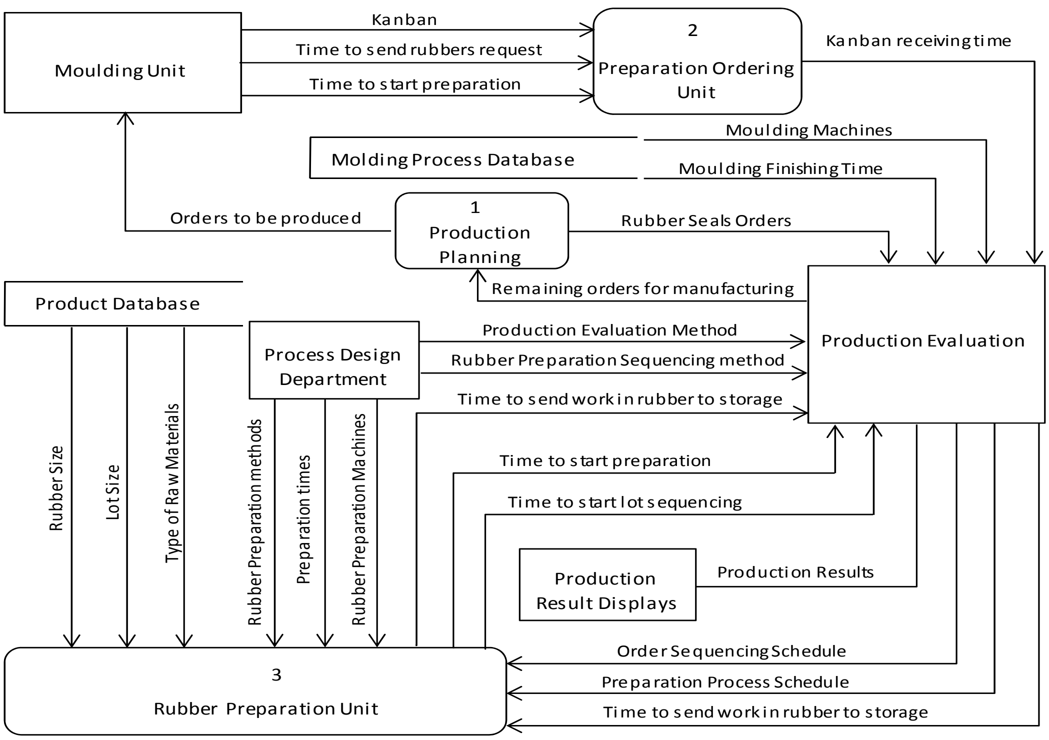


Figure 7: The Data Flow Diagram level 0 of the rubber preparation process

4.3 DFD Level 1

Since the system considered in this paper is complicated and related to a large amount of data, the DFD Level 0 diagram cannot describe all detailed processes. This section utilizes DFD Level 1 to illustrate the following process:

1. DFD Level 1 of production planning shows the relationships of orders information, finished goods information, and production information in order to process and display production results (shown in Figure 8). Three sub processes in this part are as followed:
    - Production planning requires orders information and finished goods information. After the production plans are determined, the production orders are released.
    - Production information processing uses orders, moulding and rubber preparation information to compute the remaining orders needed to be produced.
    - Finished goods reports show production status of the remaining production orders. This will give feedbacks to production planning unit and give useful information, such as the appropriate amount of materials for the next batch of production, to material planning unit.

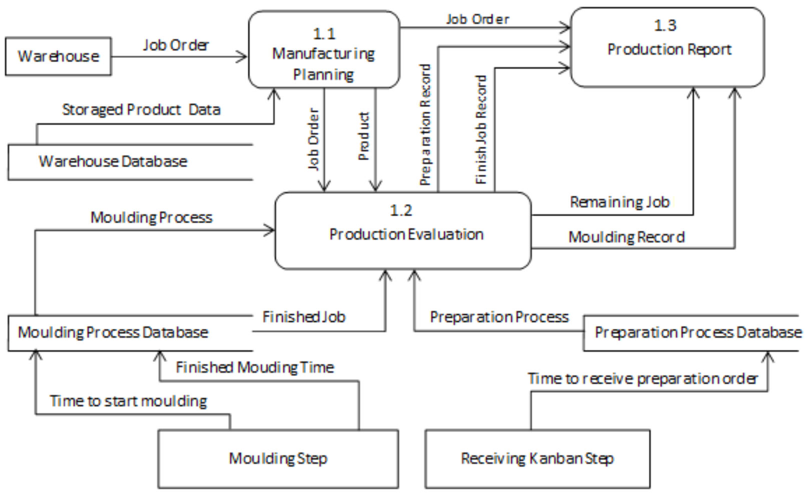


Figure 8: The Data Flow Diagram level 1 of production planning

2. DFD Level 1 of rubber preparation ordering illustrates in the relationships of information flows from moulding to preparation units (shown in Figure 9). There are five steps explained below:
    - Rubber preparation request from moulding units occurs when WIP rubbers are collected from the storage. If there are remaining jobs in the production plans, the rubber preparation of the next batch is started.
    - Rubber preparation status processing is required to smoothen the flows of each step in the rubber preparation process, from order sequencing to WIP rubber storaging.

- Rubber preparation status displays help inform workers who are responsible for each step. The display will show the message “OK” in green color if the process in that step is correctly completed. If there is a problem, that job order will be displayed in red and attention will be required. The example of status table designed for the rubber preparation process is shown in Figure 10.
- WIP rubber storage status is displayed to report lists of jobs completely prepared and ready for the next moulding process. It shows the lists of jobs taken from the storage as well as time of leaving. Figure 11 illustrates an example of WIP storage status displays designed for this E-Kanban system.

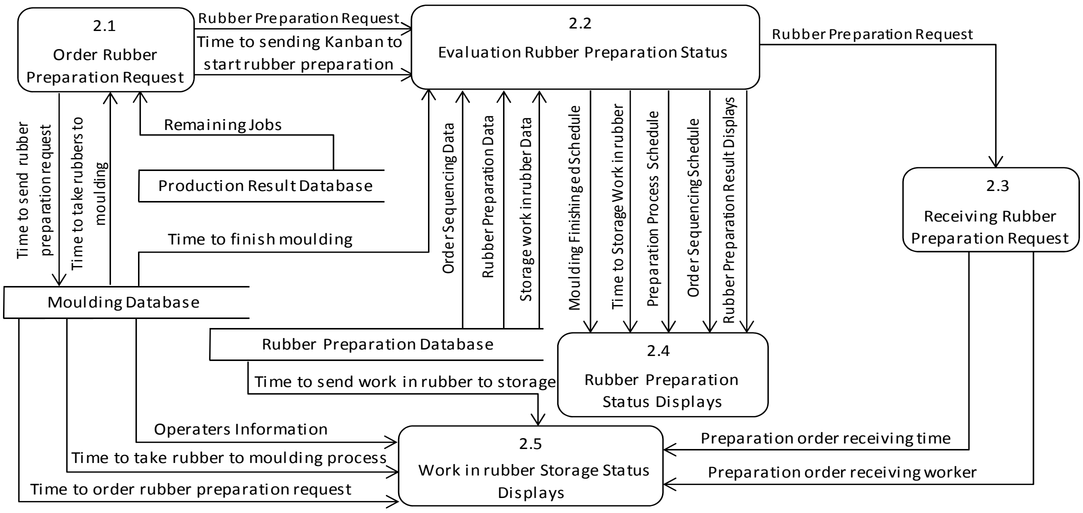


Figure 9: The Data Flow Diagram level 1 of rubber preparation ordering

Rubber Preparation Process Status Table

Machine	Current Lot			Next Lot								
	Product Code	Finish Moulding		Product Code	Start Preparation		Storage Schedule		Preparation Schedule		Sequencing Schedule	
		Date	Time		Date	Time	Date	Time	Date	Time	Date	Time
100/A	A000000-010	14-May-12	16.25	A000000-011	14-May-12	10.43	14-May-12	15.25	14-May-12	14.25	14-May-12	12.25
100/B	B000000-010	14-May-12	16.42	B000000-011	14-May-12	9.55	14-May-12	15.42	14-May-12	14.42	14-May-12	12.42
100/C	C000000-010	14-May-12	17.45	C000000-011	14-May-12	11.15	14-May-12	16.45	14-May-12	15.45	14-May-12	13.45
100/D	D000000-010	14-May-12	18.06	D000000-011	14-May-12	10.38	14-May-12	17.06	14-May-12	16.06	OK	OK
101/A	E000000-010	14-May-12	18.33	E000000-011	14-May-12	9.42	14-May-12	17.33	14-May-12	16.33	OK	OK
102/E	H000000-010	14-May-12	19.35	H000000-011	14-May-12	10.53	OK	OK	OK	OK	OK	OK
102/F	I000000-010	14-May-12	19.43	I000000-011	14-May-12	10.11	OK	OK	OK	OK	OK	OK
200/A	J000000-010	14-May-12	17.51	J000000-011	14-May-12	9.58	OK	OK	OK	OK	OK	OK
200/B	K000000-010	14-May-12	20.06	K000000-011	14-May-12	13.48	14-May-12	19.06	14-May-12	18.06	14-May-12	16.06
200/C	L000000-010	14-May-12	15.47	L000000-011	14-May-12	8.18	OK	OK	OK	OK	OK	OK

Date: 14-May-2012 **Time : 15.20.11** REFRESH EXIT

Figure 10: The E-Kanban status table designed for the rubber preparation process

Work In Rubber Storage Status Table

Excel Output 14 / 5 / 2012 10.50.23

Storage Number	Preparation Order			Order Receiving			Storage Entering			Storage Leaving		
	Kanban ID	Time	Employee	Kanban ID	Time	Employee	Kanban ID	Time	Employee	Kanban ID	Time	Employee
R0001	K0001	10.00	suwat	K0001	10.45	sompong	K0001	16.40	105003	K0001	18.00	105003
R0002	K0002	10.30	suwat	K0002	10.45	sompong	K0002	17.00	105003	K0002	19.15	105003
R0003	K0003	10.45	suwat	K0003	11.30	sompong	K0003	17.00	101051	-	-	-
R0004	K0004	11.00	suwat	K0004	11.30	sompong	K0004	17.30	101051	-	-	-
R0005	K0005	11.00	suwat	K0005	11.30	sompong	-	-	-	-	-	-
R0006	K0006	11.15	suwat	K0006	11.30	sompong	-	-	-	-	-	-
R0007	K0007	11.50	suwat	-	-	-	-	-	-	-	-	-
R0008	-	-	-	-	-	-	-	-	-	-	-	-

REFRESH EXIT

Figure 11: The work in rubber storage status table

3. DFD Level 1 of rubber preparation processing shows the relationship of information flow in each step under preparation process (shown in Figure 12). Three steps in this part are as followed:
   - Rubber sequencing prepares jobs according to their priorities. If there are no other jobs in the list, the coming job will be assigned with the highest priority. If there are other jobs in the list, the coming job will be determined its priority by comparing its calculated starting time of preparation process. Figure 13 shows the example of sequencing schedule table designed for this step
   - After order sequencing, jobs will be sent to preparation process in orders. After each job is completed, the job information will be sent back to the system so that it will be ready for the next step.
   - When the preparation is completed, WIP rubbers will be sent to the storage, the finishing time will be recorded in the system as a signal that the jobs are ready for the moulding process.

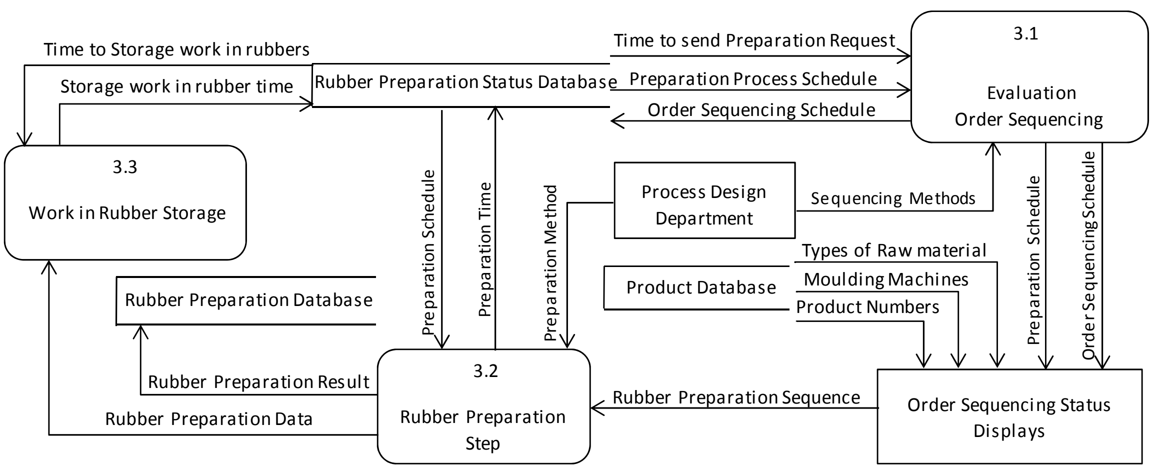
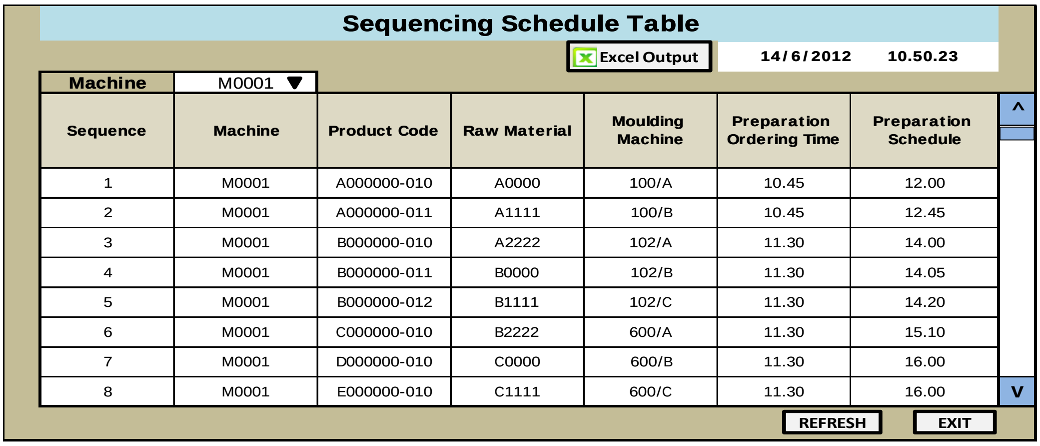


Figure 12: The Data Flow Diagram Level 1 of rubber preparation processing



Sequencing Schedule Table

Excel Output   14/6/2012   10.50.23

Machine: M0001

Sequence	Machine	Product Code	Raw Material	Moulding Machine	Preparation Ordering Time	Preparation Schedule
1	M0001	A000000-010	A0000	100/A	10.45	12.00
2	M0001	A000000-011	A1111	100/B	10.45	12.45
3	M0001	B000000-010	A2222	102/A	11.30	14.00
4	M0001	B000000-011	B0000	102/B	11.30	14.05
5	M0001	B000000-012	B1111	102/C	11.30	14.20
6	M0001	C000000-010	B2222	600/A	11.30	15.10
7	M0001	D000000-010	C0000	600/B	11.30	16.00
8	M0001	E000000-010	C1111	600/C	11.30	16.00

REFRESH   EXIT

Figure 13: The sequencing schedule table designed for rubber sequencing process

5. IMPREMENTATION RESULTS

From the system designs presented in the previous sections, together with the factory management team, we developed E-Kanban system written in Visual C++ version 6.0 and Postgresql as its information management system. Nine computers were installed to operate this E-Kanban system: one at production planning department, one at WIP rubber storage, one at the head of rubber preparation process office and six computers in front of six rubber preparation machines.

After E-Kanban system installation and implementation, we recorded the number of rubber delays during July 2012 to October 2012. The total number of delays was 86 and only 11 of them (or 12.79% of all delays) were from rubber preparation process. Figure 14 presents the number of rubber delays from January to June 2012 and July to October 2012 (before and after E-Kanban implementation, respectively). The delays were distinguished according to their causes. We can see that most of the delays shown in Figure 14 are from other reasons which are not from the rubber preparation process. It has shown that the designed E-Kanban system can significantly reduce the number of delays and improve production productivity.

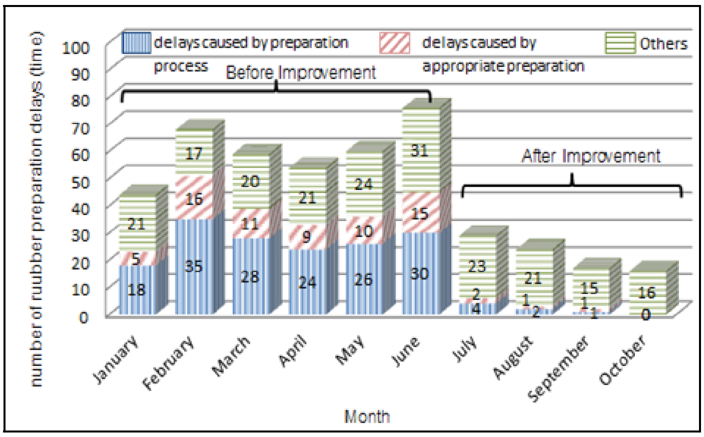


Figure 14: The number of rubber delays from January to June 2012 and July to October 2012 (before and after E-Kanban implementation, respectively)

6. CONCLUSIONS

In this paper, we developed a method to identify appropriate times for each step in the rubber preparation process and designed information management for the Electronic Kanban System (E-Kanban) for a case study automotive parts factory. The goal was to reduce the number of rubber delays by designing a practical E-Kanban to replace the traditionally manual card system previously used. In time signaling design, we proposed a method to find the following components: (1) the maximum total time in the rubber preparation process, (2) the finishing time for rubber preparation, (3) the starting time for rubber preparation, and (4) the starting time for rubber sequencing. We studied each step of the preparation process, described data input, data output and their relationship using the context diagram and data flow diagram (DFD). After the developed E-Kanban system was implemented in the factory from July to October 2012, we found that the number of rubber supplying delays could be reduced to 86 events and only 11 events or 12.79% of these delays are from the rubber preparation process. In addition to the ability in reducing delays, this designed E-Kanban system helped decrease human errors in placing manual Kanban cards and smoothen the process flow as all signals are automatically sent to each step. The idea of the design presented in this paper can be used as a framework of E-Kanban system design for other departments with comparable production.

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