Process Mining In Corrugated Boxes Manufacturing Industry - A Case Study

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Abstract: Process mining techniques are applied for extracting process knowledge from event logs recorded by an information system. The information in the event logs are rarely used to analyze the process, so the first step is to analyze the present processes. The process mining methodology is applied to analyze the corrugated boxes manufacturing industry for process discovering. The corrugated boxes manufacturing industry is looking out to simplify their processes. With process mining techniques, the corrugated boxes manufacturing industry process is analyzed from three different perspectives: (a) the control flow perspective, (b) the organizational perspective and (c) the performance perspective. The relevant event logs are extracted from the corrugated boxes manufacturing unit system and these logs are analyzed. In order to do so, it is essential to have an accurate view of the workers work load. Process mining methodology is used to obtain meaningful knowledge about the flow, i.e., to discover typical path used for manufacturing a cardboard box with a particular size, thickness and color which is assigned for the workers to execute the task. This is a nontrivial task specifying the dynamic nature of manufacturing processes. The research paper focuses on the applicability of process mining in the manufacturing sector using organizational perspective. The mining results shows that process mining can be used to provide new approach that facilitate the improvement of existing workers work load, thus it leads to efficacy.

Keywords: Process Mining, Organizational Perspective, ProM Framework

1. INTRODUCTION

In the dynamic competitive market the needs and expectations are always changing. It is very difficult to maintain and execute actions against other organizations. The process of an industry such as corrugated boxes production has to focus on ways to make more efficient processes in order to deliver high quality product while at the same time reducing costs. The organizational perspective is examined by focus on “who” performs the different tasks and how operators are related. Process mining aims at extracting process knowledge from event logs, which may originate from all kinds of information systems. The event logs contain information about the start and completion of activities with reference to related context data (e.g. workers and resources). Process mining is a very broad area both in terms of applications and techniques. The process mining methodology is also called as workflow mining methodology. This is been developed for filtering a structured process description from a set of real executions [1]. According to literature, various research works on process mining were carried out in different fields like healthcare process for identifying patient’s care flows and collaboration between departments [2] and mining process in dentistry using process perspective and organizational perspective. This research paper provides an insight about corrugated boxes manufacturing industry, since not much work is done in this regard. Current research paper focuses on the applicability of process mining in the corrugated boxes manufacturing unit. Process mining can be applied for obtaining new approach related to organizational flows. “Identification of organizational paths and the comparison between different workers to minimize the work load and the cost of production are the focal point”. The interaction between the workers can be calculated from the occurrence of handing over of work from one operator to another.

The research paper describes a case study based on raw data of the corrugated boxes manufacturing unit, located in Chennai. Raw data contains details about different size and thickness of corrugated boxes. The data has been recorded in the system to analyze the workers work flow. Application of Business Intelligence tools focuses on performance indicators such as the number of jobs to be performed i.e., manufacturing the particular size and thickness of boxes as per the requirements of the customers. Process mining looks “inside the process” at different abstraction levels. In the context of a corrugated box, unlike Business Intelligence tools, we are more concerned with the organizational paths followed by individual workers, where certain procedures are followed or not.

The research paper is organized into 7 sections. Each section performs predetermined task. Section 1 and 2 introduces the concept of process mining. Section 3 deals
with the applicability of process mining in the corrugated boxes manufacturing unit. Section 4 describes about the data set. Section 5 discuss about social network mining of the corrugated boxes manufacturing unit process. Section 6 presents the results of process mining. Section 7 presents the conclusion.

2. PROCESS MINING: AN OVERVIEW

Process mining is a field of analysis technique that focuses on mining behavioral aspects from log data. The systems may be pure information systems (e.g., ERP systems). The only requirement is that the system produces event logs, thus recording the actual behavior [2]. The main idea of the process mining methodology is to discover, examine and progress real processes by extracting knowledge from event logs. Lots of information about processes is recorded by information systems in the form of “event logs”. The aim of process mining is to learn about processes by observing them through event logs. The process mining methodology works on a set of event data that are collected from an information system, which supports and controls the operational processes. After extracting event records from that information system, event logs are generated and stored with a predefined format, which is specially designed for the process mining applications. Applying prepared event log, process models are extracted using process mining algorithms.

2.1 Process Mining Perspective

Process mining can be focused on different perspectives/fields: (a) the process perspective – “How the process occurs”, (b) the organizational perspective – “Who performs the job or task” and (c) the case perspective – “What are the tasks to be performed”.

(a) Process perspective aims at ordering of the activities and helps to locate possible path in terms of a Petri net [3].

(b) Organizational perspective focuses on the originator [4], i.e., which performers are involved in the process model and the way they are related. The main goal is to typify the originators in terms of their roles and their association with other performers.

(c) Case perspective concentrates on properties of cases. Each case is characterized by its own path in the process or by the creators (originators) working on a case, e.g., if a case represents a job it is interesting to know the number of jobs completed.

In each of the above perspectives, there are three orthogonal aspects: (1) Discovery, (2) Conformance, and (3) Extension.

Discovery: There is no a-priori model, i.e., based on an event log some model is constructed. For example, using the well-known alpha algorithm [5] a Petri net model can be constructed which describes the behavior observed in the event log. “To reveal the process of corrugated box manufacturing, information about size, thickness, and color of the box is stored in their in-built information system”.

Conformance: There is an a-priori model. This model is used to check if reality conforms to the model [6]. For example, there may be a process model indicating the purchase orders of more than one million Euro requires two checks. Or to check the recorded patients event log conforms to the model. It helps to check whether the modeled behavior matches the observed behavior. Conformance checking may be used to identify deviations to locate and explain these deviations, and to measure the severity of these deviations.

Extension: There is an a-priori model. This model is extended with a new aspect or perspective, i.e., the goal is not to check conformance but to enrich the model. An example is the extension of a process model with performance data, i.e., some a-priori process model dynamically annotated with performance data. There is a tool such as the ProM framework [7] which features a wide set of analysis techniques which can be applied to real life logs while supporting the whole range as shown in figure 1.

3. CORRUGATED BOXES MANUFACTURING PROCESS

Over whelming demand of the customer forces the manufacturer to manufacture very strong corrugated boxes in order to stand out in the competitive world. The boxes are made up of corrugated paperboard that is different from the rigid paper called as cardboard. The boxes are used to hold things to protect it from damaging and keeping it from leaking. Boxes are printed with important information on them about what is inside or
how to carry or move them. It is carefully designed to insert, hold items in place so they won’t spill or be damaged.

3.1 Steps in Box Building

Corrugating machine is designed to do continuous process which brings together three, five or seven sheets of paper to form single, double or triple wall corrugated board. Strong boxes can be made from different layers like 3 layers or 5 layers of flutes. The first work is to mix dry corn starch with water and other chemicals and push it into the corrugators to spread on the corrugated medium as the layers of liner are added. A box can be made by the corrugated board on a sequence of connected machines called a corrugating line.

Corrugation – The corrugators are fed with reels of paper as shown in figure 2. The paper is hardened with heat and steam which is passed between corrugating rolls. This process gives the paper a flute shape (wavy layer) in the single facer. The roll of paper is pulled between a pair of gear like cylinders called corrugating rolls as shown in figure 3. This forms the paper into a series of particular waves. Glue is applied to the tips of the flutes on one side at the right places and the flute tips are pressed against a flat liner. This creates a corrugated board, i.e., a continuous sheet of flat paper with fluted paper glued to it. The corrugated board is so stiff that it cannot be rolled up; this is cut into flat sheets as per the required size to make the boxes which has been ordered. The corrugated board are then arranged and set aside so the glue can dry properly and after that it is sent to the next process.

![Figure 2](image2.png)

**Figure 2** Corrugated board production machine

![Figure 3](image3.png)

**Figure 3** Corrugation process

Printing - A printing machine is used to print with bright color ink. Use graphic designs for self-supporting display feature like company name, logo, product information, etc.

Die-Cutting – Die cutting is used to cut or punch out the size and shape of corrugated paper desired.

Stitching - Stitching is used to connect the lap and the end of the sheet of a corrugated container with a metal wire.

Gluing - Gluing is like stitching but resign adhesive is sued instead of metal wire. Finally the packed or bundled boxes are ready for dispatch.

3.2 Quality Control

Quality assurance and quality check are the part and parcel of every sub stage of the process. The process starts with the supplier who supplies the Kraft paper which is used to make corrugated cardboard. Kraft paper should be smooth and strong. The main process starts from the corrugation where the paper is passed through the corrugators and is made into box boards. The individual boards are pulled from the heap and checked. The quality check measures the moisture in the liner and medium. In the manufacturing process, quality test is determined by ensuring the glue strength, bursting strength, compression, and highly accurate dimensions. The flatness of the box board is tested by warp test which assures that each board will travel easily through the machines. The workers run batches of box boards through the machines where individual boxes are pulled for quality check, i.e., for trimming, cutting, printing the color, and bundling.

In this section, we will see the applicability of process mining in corrugated boxes manufacturing unit. The in-built information systems used in corrugated box manufacturing units need to provide an integrated package to assure about the different size, thickness and color of the boxes along with minimum processing time with reduced work load.

Researchers have selected leading corrugated boxes manufacturing unit located at Chennai to showcase the applicability of process mining. Raw data contains information about the box size, thickness, flute type, color, and quantity as recorded by the unit. In these logs, information is stored about activities as they are being executed. This information can include the times at which events were executed, who executed these events. The process mining has extracted event logs from the corrugated boxes manufacturing unit, where each event refers to a different process. The event logs will show the process dynamics. The log contains real world data about the corrugation box manufacturing process, where the applicability of process mining in manufacturing unit is portrayed. The log contains 4 cases and 58 different events to represent organizational flow process. The study is focused on the discovery part of process mining.

4. DATA SET DESCRIPTION

Every process has one or more inputs. In this case, the raw data for manufacturing of corrugated boxes is the
size, flute type, quantity, and color. Corrugated board can be made up of 3 ply or 5 ply with different flute type. There are different flute types like A, C, B, E, K. The data set describes flute type, GSM (grams per Sq meter), Bursting factor, Bursting Strength, Compression Strength (ECT). The unit is backed up by manpower comprising of operators, helpers and quality manager. Set of people do different process at different stages. ProM6 tool uses the MXML format [8] or XES format. In the case study the format of the corrugated box manufacturing unit data was mapped onto the MXML format.

5. Methodology
Researchers present some results obtained through a detailed analysis of the corrugated box manufacturing unit which generate event logs. Based on the organizational flow perspective, researchers have used process mining tools namely ProM framework. An open-source application, ProM framework is available for executing different types of process mining algorithms. In this paper, focus is on organizational flow of activities. The view of organizational perspective deals about the social relationship amongst workers and organization structure of working environment. This helps to identify and minimize or maximize the workers work load of the production in corrugated boxes manufacturing unit.

5.1 Organizational Perspective
The organizational perspective is focused on “who” performs the different task and how performers are related. Workers interaction can be calculated from the occurrence of handing over of work from one performer to another. In this paper, emphasis is on social network mining to provide new approach into the relationship between different workers in the manufacturing unit. The Social Network Miner allows the discovery of social networks from process logs. There are several social network analysis techniques and research results available, the generated social network allows for analysis of social relations between originators involving process executions.

To derive the network, the researchers used the mining techniques like Work Together Social Network, Handover Task Social Network, and Similar Task Social Network [5] that determines the frequency of transfer of work among workers in the manufacturing unit. The network shows the relationships between the originators. Solid circle represents the worker (Operator, Helper or Quality Manager). Each circle can be denoted as a node with a receiving edge and an assigning edge. The receiving edge accepts the job and the assigning edge assigns the job.

6. Results of Social Network Mining in Corrugated Boxes Manufacturing Unit
The social network mining technique is used to derive process models from event logs. By analyzing an event log it is possible to analyze the relation between resource and activities. This social network mining method is to know more about people, machines, organizational structure (jobs and sectors), work distribution and work patterns. Process in the corrugated box manufacturing has multiple work flow with variants based on different size, thickness and colors. Figure 4, 5 and 6, represents the work together task, handover task and similar workgroups with similar task processed by analyzing all the log events.

6.1 Mining for Work Together Social Network Model
The corrugated boxes manufacturing unit consists of different jobs (process) where different types of workers work together to complete the work. Working together model is based on joint case and not on joint activities. Two individuals work together if they perform activities in the same case of an event log.

![Image](image)

**Figure 4 Mining for Work Together Social Network Model**

Work Together Social Network model counts frequency of individuals work in the same case, and helps to identify the different teams. “The result after mining shows that all the operators and helpers are highly involved in the job and many workers interact with each other”. Figure 4 and Table 1 shows that all the process is interdependent amongst the workers at each level and the participation of the workers must be the maximum.

**Table 1: Work Together Social Network Model**

<table>
<thead>
<tr>
<th>Operator</th>
<th>Helper A</th>
<th>Helper B</th>
<th>Helper C</th>
<th>Helper D</th>
<th>Helper E</th>
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<th>Operator 2</th>
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6.2 Mining for Handover-Task Social Network Model

Model of Handover determines who hands over work to whom. Each activity is handed over to other workers to complete a sequence or cycle of process. Handover of task model measures the occurrence of transfer of work amongst the workers. The mining results are useful to detect existence of frequent interactions between different originators (Operators and Helpers).

Figure 5 and Table 2 depicts intense handover operations from corrugations to printing section. The job of corrugation is completed by Operator2 and Helper2 then handed over to Operator3 and Helper3 of printing section. After printing, the job is handed over to gluing or stitching section depending on the requirement. Entire handover task is maneuvered by quality manager.

![Figure 5 Mining for Handover-task Social Network Model](image)

Table 2: Handover Task Social Network Model

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<th>Operator/Helper</th>
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<th>Operator3</th>
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6.3 Mining for Similar Task Social Network Model

Similar Task model extracts information about workers who perform the similar task. The information is extracted based on each individual’s own profile which highlights repetition of their work performance. Similar task focuses on joint activities.

The corrugated boxes manufacturing unit manufactures boxes based on the number of flutes or number of ply. The corrugation is the major work done and this is performed by the Operator2 and Helper2, the quality manager is the person who checks the quality and allots the work.

Figure 6 and Table 3 shows the importance of quality manager as he is a better person to allocate the work load to other workers. Model has generated maximum value to Operator2 and Helper2 as their involvement, in the workflow is high. The mining of event logs is helpful for the workers in the corrugation boxes manufacturing unit to minimize and maximize the work.

![Figure 6 Mining for Similar Task Social Network Model](image)

Table 3: Similar Task Social Network Model

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7. CONCLUSION

Application of process mining is illustrated effectively using corrugated boxes manufacturing unit located at Chennai. Data from nontrivial process of the corrugated boxes is pooled up into the organization process by
organizational perspective. The data is analyzed using effective process mining tools to obtain the results. The process mining techniques enabled the researchers to obtain clear Work Together Social Network model, Handover-Task Social Network model, and similar work group with Similar Task Social Network model. It is a scientific approach to analyze all the processes using event logs. Work Together Social Network model emphasizes that all the processes are interdependent and the participation of the workers must be the maximum. Handover-Task Social Network model highlights the importance of the quality manager for the overall quality assurance and the quality control. Operator2 and Helper2 have scored maximum values highlighting their high workload. Mining for Similar Task Social Network model clearly generates the minimum and maximum workflow for the workers. The results are as per the recorded information and the automated mined process which helps the operators and helpers for additional measures to improve the corrugated boxes process efficiently.

References


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