Extracting Manufacturing Process Map in the Form of the IDEF Model Prerequisite for the Implementation of PFMEA in the Sugar Industry

Mohammad Baghbani¹, Soleyman Iranzadeh²*, Majid Bagherzadeh Khajeh³

¹Ph.D. Student, Department of Industrial Management, Tabriz Branch, Islamic Azad University, Tabriz, Iran
²Associate Prof, Department of Industrial Management, Tabriz Branch, Islamic Azad University, Tabriz, Iran
³Assistant Prof, Department of Management, Tabriz Branch, Islamic Azad University, Tabriz, Iran

*Email of Corresponding Author: Dr.iranzadeh@yahoo.com

Received: January 14, 2019; Accepted: April 6, 2019

Abstract
The purpose of this research is to demonstrate the importance of extracting business process mappings as a prerequisite for the implementation of the PFMEA (Process Failure Mode and Effect Analysis). In the first stage, 30 production process failures were extracted in the meetings with factory managers. Then, a team was formed by the presence of process owners, and with the help of the project team, the production process map was drawn up according to the IDEF0 standard. In the next step, for the second time, potential failures were extracted according to the production process map. This time, 49 failures in the production process with the potential sources of failures were identified. The results of the study showed that by extraction of the production process map, more failures in the production process would be detectable. In fact, extraction of the process map is a prerequisite for the implementation of the PFMEA. In this research, in order to better describe the steps taken, all extracted processes are schematically illustrated in accordance with the IDEF0 Modeling Standard, so that other sugar-producing companies can also use them to implement the PFMEA. The innovative aspect of this research is to extract the production process failures before and after extracting the process map and compare them with each other.

Keywords
Process Map, IDEF0, PFMEA, Modeling

1. Introduction
The important advantage of process representation over traditional organizational approaches is that it provides a structure of actions. Several process modeling methodologies are currently available and used by various companies. To increase the likelihood of a successful change, a comprehensive modeling methodology is required. The methodology developed should help to anticipate the reaction of process participants to the proposed changes [1]. The IDEF0 technique is a powerful analysis tool that describes business environments through activities and concepts [2].
2. Literature Review

2.1 IDEF0

The IDEF0 technique was developed during the seventies by the US Air force as part of its Integrated Computer-Aided Manufacturing program, which was involved in a method for modeling functions of an organization (decisions, actions, and activities) and the relationship between those functions [2]. IDEF standard was developed with the assumption of improving manufacturing productivity using IT and modeling and represents a set of standardized methods and languages for information modeling in the field of software engineering towards the improvement of the business process [3].

IDEF0 is used to produce a function model which is a structured representation of the functions of a manufacturing system or environment and of the information and objects which interrelate those functions [4]. The IDEF0 language is an updated version of the Structured Analysis and Design Technique (SADT) proposed by D. Ross in 1976 for a structured analysis of systems. It is accepted in the USA as a federal standard. The resulting model expresses knowledge about how a system, process, or organization works. IDEF0 describes the specific steps of a process course and the relationships developed. It also records the information flows, resulting from these relationships. Finally, IDEF0 model includes a set of syntax components essential for BP integration. The syntax components include boxes, arrows, and diagrams. Boxes represent functions, defined as activities, processes or transformations. Arrows represent data or objects related to the functions. The format also provides the basis for model configuration management. For the application of IDEF0 on modeling tasks, we choose Workflow modeler due to its ease of use and its ability to provide the whole set of syntax components of IDEF0 language. Workflow modeler is a standalone software due to its features [5].

The goal of newly developing IDEF techniques is to enable experts to comprehend problems from different views and levels of abstraction. In this regard, integrated IDEF methods present basic tools of some modern strategies and methodologies of business process improvement, for example: BPR (Business Process Reengineering), CPI (Continuous Process Improvement), IPD (Integrated Product Development), JIT (Just-in-Time), PPC (Production Planning and Control), QFD (Quality Function Deployment), TQM (Total Quality Management), TPM (Total Productive Maintenance), etc. [3]

Ang. C.L. Luo et al. conducted research on the development of a Knowledge-based Manufacturing Modeling System based on IDEF0 for the metal-cutting industry. A model for integrating process planning and production planning and control in machining processes was reviewed by Ciurana, J. et al. Hernandez-Matias, J.C. et al. reported on an integrated modeling framework to support manufacturing system diagnosis for continuous improvement. Kang, H.W. et al. commented on unified representation of the physical process and information system. Development of a novel simulation modeling system for distributed manufacturing was presented by Qin, S.F. et al. Eldabi, T et al. made an evaluation of tools for modeling manufacturing systems design with multiple levels of detail [3].

A business process has the following elements:

- A business process has its customers.
- A business process is composed of activities whose objectives are to create value for customers.
Activities are performed by actors who may be humans or machines.
- A business process often involves organizational units which are responsible for the whole process.

IDEF methods will support those elements. For example, IDEF0 was designed to capture the ‘decisions’ and ‘activities’ of a system. Those decisions and activities include information on what functions the system performs, what constraints the functions have, what the functions' needs are, and what input and output are meaningful in performing those functions. An IDEF0 model is represented by rectangles with four different types of arrows surrounding the rectangles. A rectangle represents a function or activity described in a verbal phrase, and the arrows represent (1) “Input” (on the left); (2) “Output” (on the right); (3) “Control” (on the top); and (4) “Mechanism” (on the bottom) called (ICOM) described in a noun phrase to explain the behavior of the function (see Figure 1 below). It also supports the hierarchical decomposition of activities for an appropriate abstraction of a system. We notice that the first three business elements could be supported by IDEF0. For example, IDEF0 model could be developed from a specific customer’s perspective and context - first element. The business activities are part of system activities - second element. The mechanism in ICOM includes actors - third element.

2.2 PFMEA
The first official use of FMEA was in the aerospace and automotive industry, and on issues related to health and safety during the mid-1960s [6-10]. In the various researches, FMEA has been considered as a useful and powerful tool for evaluating potential failures and preventing their occurrence [11, 12]. The FMEA is a team-based systematic tool used to define, identify, evaluate, prevent, eliminate or control the modes, causes, and effects of potential failures in a system, process, design, or service, within a system for classification by the severity and likelihood of the failures, before a product or service reaches to the final customer [13, 14]. The priority of each of the failure modes in the FMEA is identified by calculating the risk priority number (RPN) in terms of the product of the three components: Severity of the failure (S), the probability of Occurrence (O) and the difficulty of detecting of the failure mode(D) [15]. Because in this technique, the ranking of each of the three components is based on numbers from 1 to 10, the calculated RPN can be a number between 1 and 1000, in other words:
The higher the risk priority number (closer to 1000), the greater the risks and failures of the manufacturing and service processes. In these conditions, the cause or causes must be quickly identified by the FMEA team [8]. The purpose, methodology and other details of FMEA technique depend on its type; in most of the relevant FMEA texts, it is divided into four types: Service FMEA, Process FMEA, Design FMEA, and System FMEA [16]. The process failure mode and effects analysis (PFMEA) technique are used to analyze and evaluate potential failures in the production and assembly process [17, 18]. This tool identifies the effects of failures and recognizes the necessary steps to remove or mitigate the failures. The reason for using PFMEA is the continuous improvement of the product and process to increase customer satisfaction. PFMEA supports other quality tool and actions and also supports preventing problems and continuous improvement, which are key elements of comprehensive quality management [19].

3. Research Methodology

To extract production failures, according to the principles of the FMEA tool in the production process, initially, production process failures were extracted in the meetings with factory managers. Then a team was formed by the presence of process owners, and with the help of the project team, the production process map was drawn up according to the IDEF0 standard. In the next step, for the second time, potential failures were extracted according to the production process map. The scale of the process map which helps in analyzing and identifying failures was studied.

4. Findings

In this research to implement PFMEA (Process Failure Mode and Effect Analysis), a team was formed with the participation of all managers and process owners. At first, 30 possible failures in the sugar production process were identified by the project team. In the table below, the failures in the first stage that were identified are presented.

<table>
<thead>
<tr>
<th>Row</th>
<th>Potential Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brix higher than 60</td>
</tr>
<tr>
<td>2</td>
<td>Brix lower than 57</td>
</tr>
<tr>
<td>3</td>
<td>Low volume of syrup relative to the desired volume</td>
</tr>
<tr>
<td>4</td>
<td>High volume of syrup relative to the desired volume</td>
</tr>
<tr>
<td>5</td>
<td>Not having a bowl in the range of 12 to 15</td>
</tr>
<tr>
<td>6</td>
<td>The shortage of gas produced in steam boilers</td>
</tr>
<tr>
<td>7</td>
<td>Transfer of low carbon to syrup</td>
</tr>
<tr>
<td>8</td>
<td>PH higher than 8.6</td>
</tr>
<tr>
<td>9</td>
<td>PH lower than 8.3</td>
</tr>
<tr>
<td>10</td>
<td>The syrup is not broken</td>
</tr>
<tr>
<td>11</td>
<td>Brix higher than 51</td>
</tr>
<tr>
<td>12</td>
<td>Brix lower than 49</td>
</tr>
</tbody>
</table>
In the second stage, all activities and processes necessary for sugar production were thoroughly studied and analyzed, after identifying the production sub-processes, inputs, outputs, mechanisms, process controls and the relationship among production sub-processes together, the process map was schematically derived by using the IDEF modeling logic and by the iGrafx software in the form of IDEF0 and IDEF3 modeling techniques. Once again, the possible failures of the production process were extracted by the project team. This time, 49 major failures were identified in the production process. The results of the research showed that the extraction of the production process map leads to a better diagnosis of failure and a comprehensive view of them, and in fact extraction of the process map is a good prerequisite for the implementation of the PFMEA.

In the following figures, the IDEF models of the production process are described in the Kurdistan Sugar Factory. As you can see, the use of IDEF modeling logic leads to a comprehensive understanding of all inputs, outputs, mechanisms, and process controllers, as well as the relationship among sub-processes.
Figure 2. Functional decomposition of sugar production process map

Figure 3. Decomposition of box A0; sugar production process
Figure 4. Decomposition of box A1: solving

Figure 5. The lowest level of decomposition (the process steps for A12 are shown by an IDEF process map)
Figure 6. Decomposition of box A13: purification
Figure 7. Decomposition of box A2: boiling in aparate
Figure 8. The lowest level of decomposition (the process steps for evaporation are shown by an IDEF process map).

Figure 9. IDEF process map of the lowest level of decomposition; the final baking of sugar.
Figure 10. Decomposition of box A3; collectore and centrifuge

Figure 11. IDEF process map of the lowest level of decomposition; Incubator

Figure 12. IDEF process map of the lowest level of decomposition; sugar brokers
As can be seen, process modeling in the form of the IDEF standard provides a more comprehensive view of the details of organizational processes. Therefore, after extraction of the above models, the possible failures of the production process were investigated and the number of failures could be determined more than the absence of a process map. The Table 2 shows 49 failures that are identified by a complete study of activities in the process map.

Table 2. Failures identified in the production process after drawing up the process map

<table>
<thead>
<tr>
<th>Subprocess</th>
<th>Potential Failure</th>
<th>Failure Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solving</td>
<td>Brix higher than 60</td>
<td>F1</td>
</tr>
<tr>
<td></td>
<td>Brix lower than 57</td>
<td>F2</td>
</tr>
<tr>
<td></td>
<td>Low volume of syrup relative to the desired volume</td>
<td>F3</td>
</tr>
<tr>
<td></td>
<td>High volume of syrup relative to the desired volume</td>
<td>F4</td>
</tr>
<tr>
<td>Lime saps production</td>
<td>low production of Lime Sap</td>
<td>F5</td>
</tr>
<tr>
<td></td>
<td>Inappropriate quality of Lime Sap produced</td>
<td>F6</td>
</tr>
<tr>
<td>Lime Syrup (Defecation)</td>
<td>Not having a bowl in the range of 12 to 15</td>
<td>F7</td>
</tr>
<tr>
<td></td>
<td>A negative effect on PH saturation stage</td>
<td>F8</td>
</tr>
<tr>
<td>Carbon dioxide production</td>
<td>The shortage of gas produced in steam boilers</td>
<td>F9</td>
</tr>
<tr>
<td></td>
<td>Transfer of low carbon to syrup</td>
<td>F10</td>
</tr>
<tr>
<td></td>
<td>Transfer high carbon gas to syrup</td>
<td>F11</td>
</tr>
<tr>
<td>Saturation</td>
<td>PH higher than 8.6</td>
<td>F12</td>
</tr>
<tr>
<td></td>
<td>PH lower than 8.3</td>
<td>F13</td>
</tr>
<tr>
<td>Purification by Grant Pont</td>
<td>The syrup is not broken</td>
<td>F14</td>
</tr>
<tr>
<td></td>
<td>Brix higher than 51</td>
<td>F15</td>
</tr>
<tr>
<td></td>
<td>Brix lower than 49</td>
<td>F16</td>
</tr>
<tr>
<td>Filter press</td>
<td>it is not Correctly press filter and high CACO₃ at the output</td>
<td>F17</td>
</tr>
<tr>
<td>Syrup decoloring</td>
<td>Inappropriate decoloring of resin</td>
<td>F18</td>
</tr>
<tr>
<td>Vapor production</td>
<td>The steam generated is not enough.</td>
<td>F19</td>
</tr>
<tr>
<td>Syrup concentration</td>
<td>Vacuum shortage</td>
<td>F20</td>
</tr>
<tr>
<td></td>
<td>Adding sugar powder in Brix less than 89</td>
<td>F21</td>
</tr>
</tbody>
</table>
Addingsugar powder in Brix more than 90 F22  
Baking less than the required time F23  
Baking more than the needed time F24  
Making mistake in measuring Brix syrup F25  
Incomplete separation of syrup F26  
Baking to a sugar-free stage with a temperature of fewer than 102 degrees F27  
Baking transfer to sugar with less than 90 Brix F28  
Not setting more time for green sugar molding F29  
The ambient temperature is more than ideal F30  
Expecting green sugar wagons less than expected time F31  
Failure to match the speed and centrifuge time with the product of the refereeing process F32  
Low temperature of the incubator F33  
High temperature of the oven F34  
Low waiting time in the Stove room F35  
Invalid wagon layout F36  
Inappropriate humidity of the inside air F37  
Inappropriate circulation of air inside the oven F38  
Inappropriate placement of sugar beet in the blades F39  
Inappropriate performance of cutting blades F40  
Row brushes are not able to sort the cuffs F41  
Irregular movements of the guillotine when breaking parts of cuffs F42  
Smooth and unsolvable sugar F43  
Irregular fluctuation of sugar belt F44  
Forget about silicon F45  
Not working jet printer F46  
An inappropriate layout of cartons on pallets F47  
A crash of the lift F48  
Inappropriate carton placement of the conveyor belt F49

5. Results and Discussion
The effective implementation of PFMEA requires a comprehensive understanding of organizational processes. Usually, modeling techniques are used to recognize all the features of a process. The IDEF technique is one of the most commonly used modeling techniques in which all inputs, outputs, mechanisms, and controllers of each process are identified. With this tool, you can map the processes of the organization to understand the process components and requirements, to diagnose the failures of the process easier, and thus, the implementation of the PFMEA becomes more effective. According to the results of this research, it can be said that the process map is one of the
prerequisites for the implementation of PFMEA in manufacturing organizations.

6. References


