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

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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.

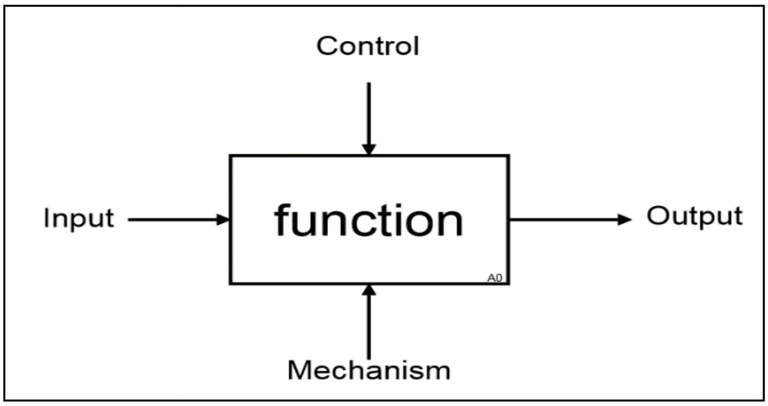

Figure1. IDEF0 process model

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:

$$RPN = S * O * D \quad (1)$$

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.

Table1. Failures detected in the first stage of the research

Row	Potential Failures
1	Brix higher than60
2	Brix lower than 57
3	Low volume of syrup relative to the desired volume
4	High volume of syrup relative to the desired volume
5	Not having a bowl in the range of 12 to 15
6	The shortage of gas produced in steam boilers
7	Transfer of low carbon to syrup
8	PH higher than 8.6
9	PH lower than 8.3
10	The syrup is not broken
11	Brix higher than 51
12	Brix lower than 49

13	it is not Correctly press filter and high $CACO_3$ at the output
14	Inappropriate discoloring of resin
15	The steam generated is not enough
16	Adding sugar powder in Brix of less than 89
17	Adding sugar powder in Brix of more than 90
18	Making mistake in measuring Brix syrup
19	Incomplete separation of syrup
20	Not setting more time for green sugar molding
21	The ambient temperature is more than ideal
22	Expecting green sugar wagons less than expected time
23	Low temperature of the incubator
24	High temperature of the oven
25	Invalid wagon layout
26	Inappropriate circulations of air inside the oven
27	Inappropriate placements of sugar beet in the blades
28	Inappropriate performances of cutting blades
29	Smooth and unsolvable sugars
30	Do not consider silicon

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.

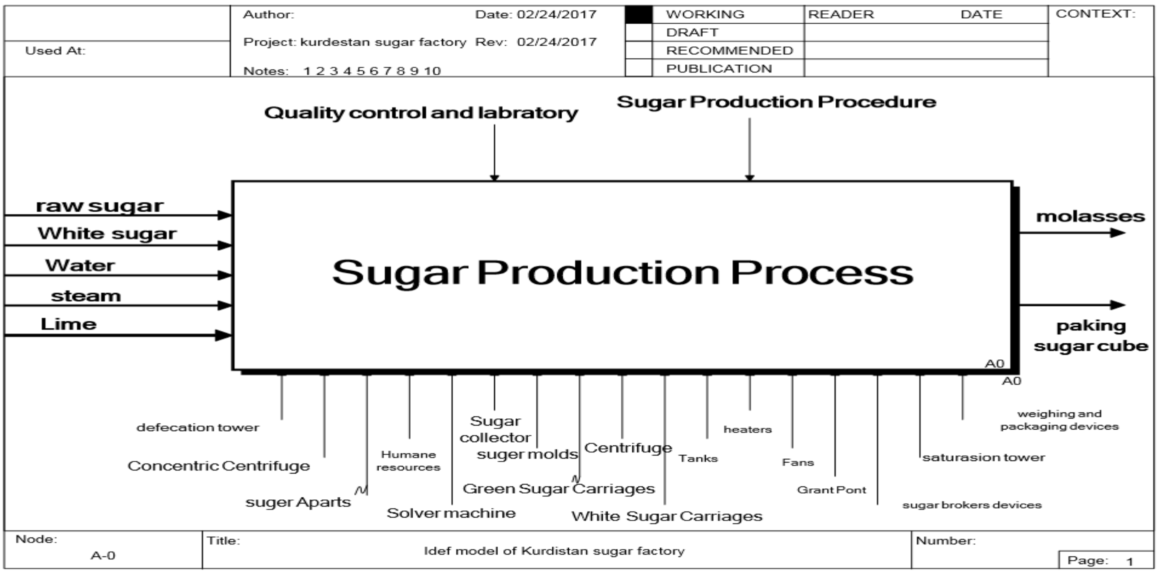

Figure2. Functional decomposition of sugar production process map

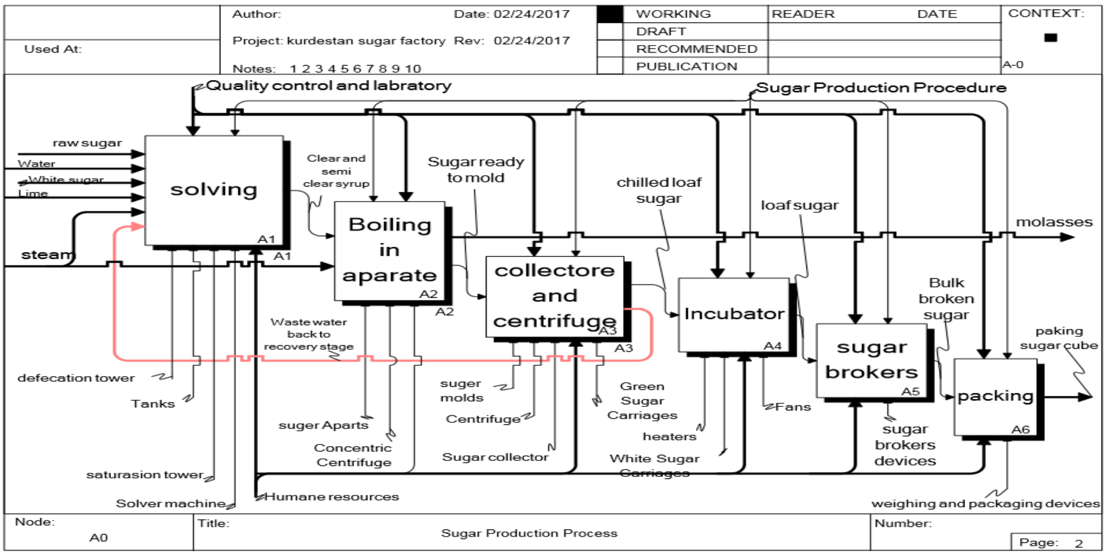

Figure3. Decomposition of box A0; sugar production process

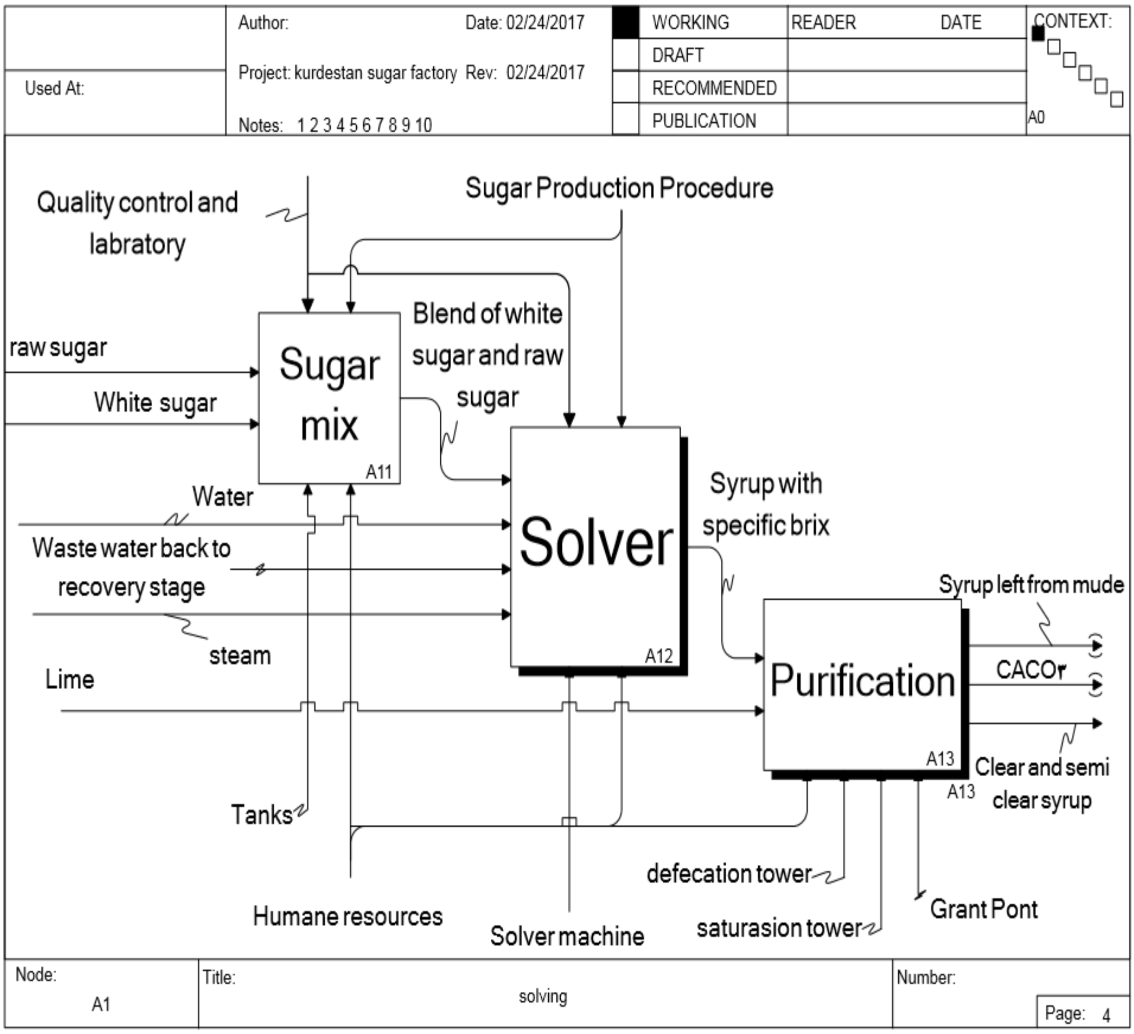

Figure4. Decomposition of box A1; solving

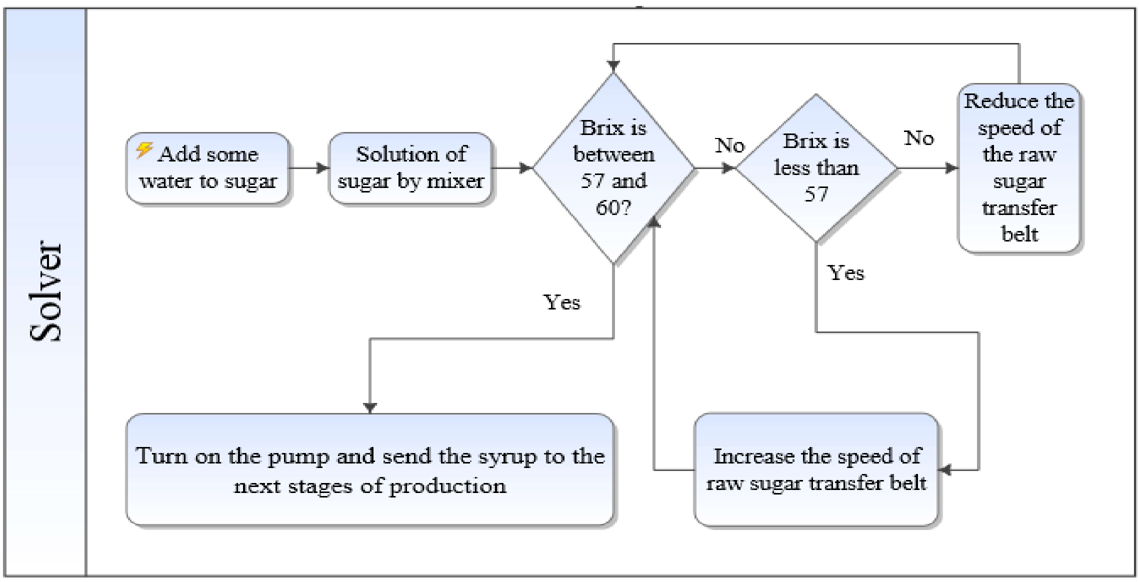

Figure5. The lowest level of decomposition (the process steps for A12 are shown by an IDEF process map)

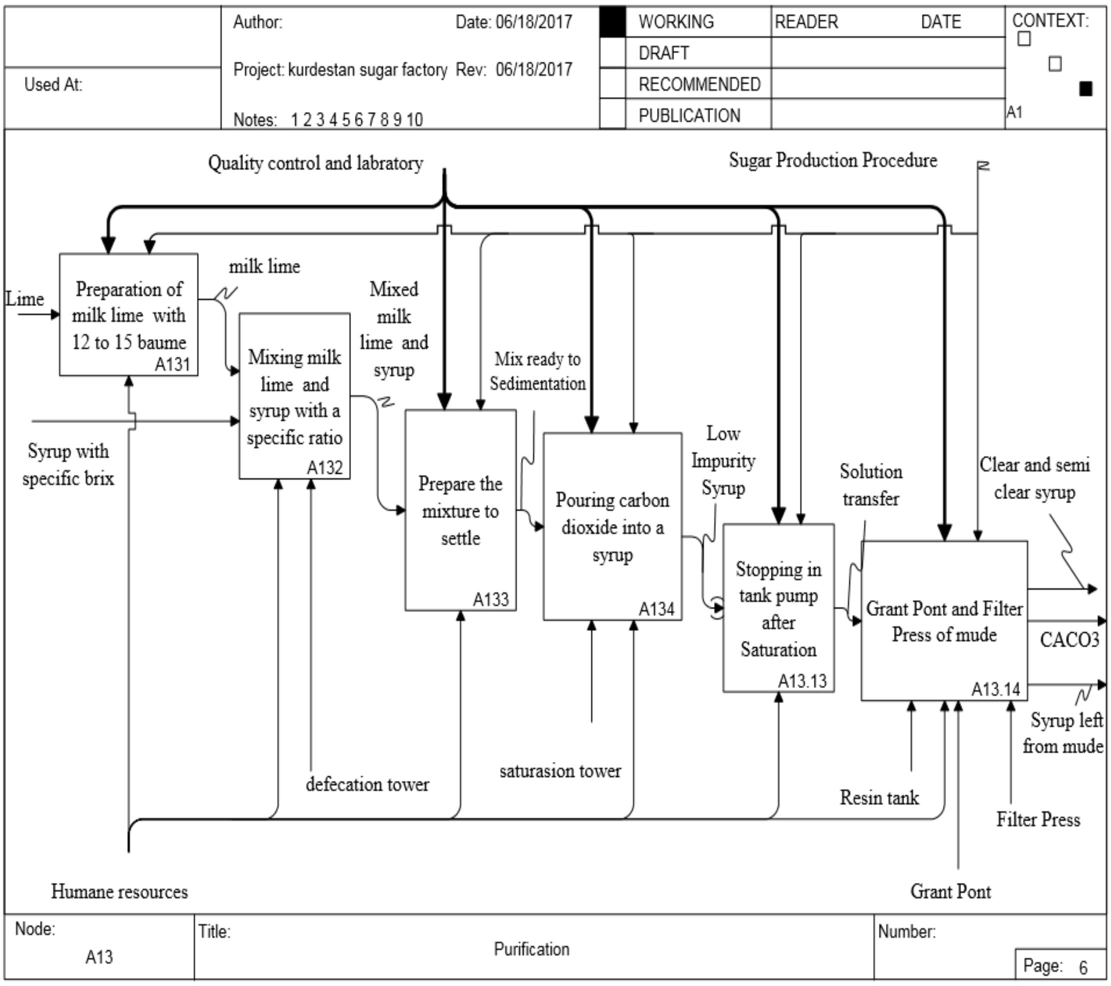

Figure6. Decomposition of box A13; purification

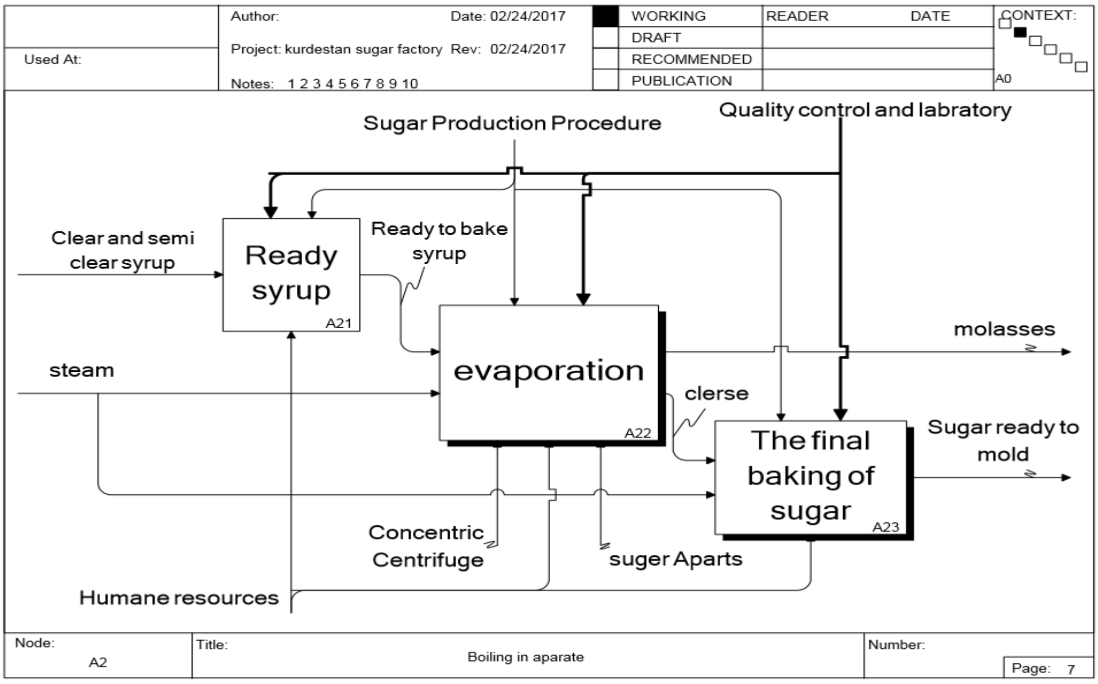

Figure7. Decomposition of box A2; boiling in aparate

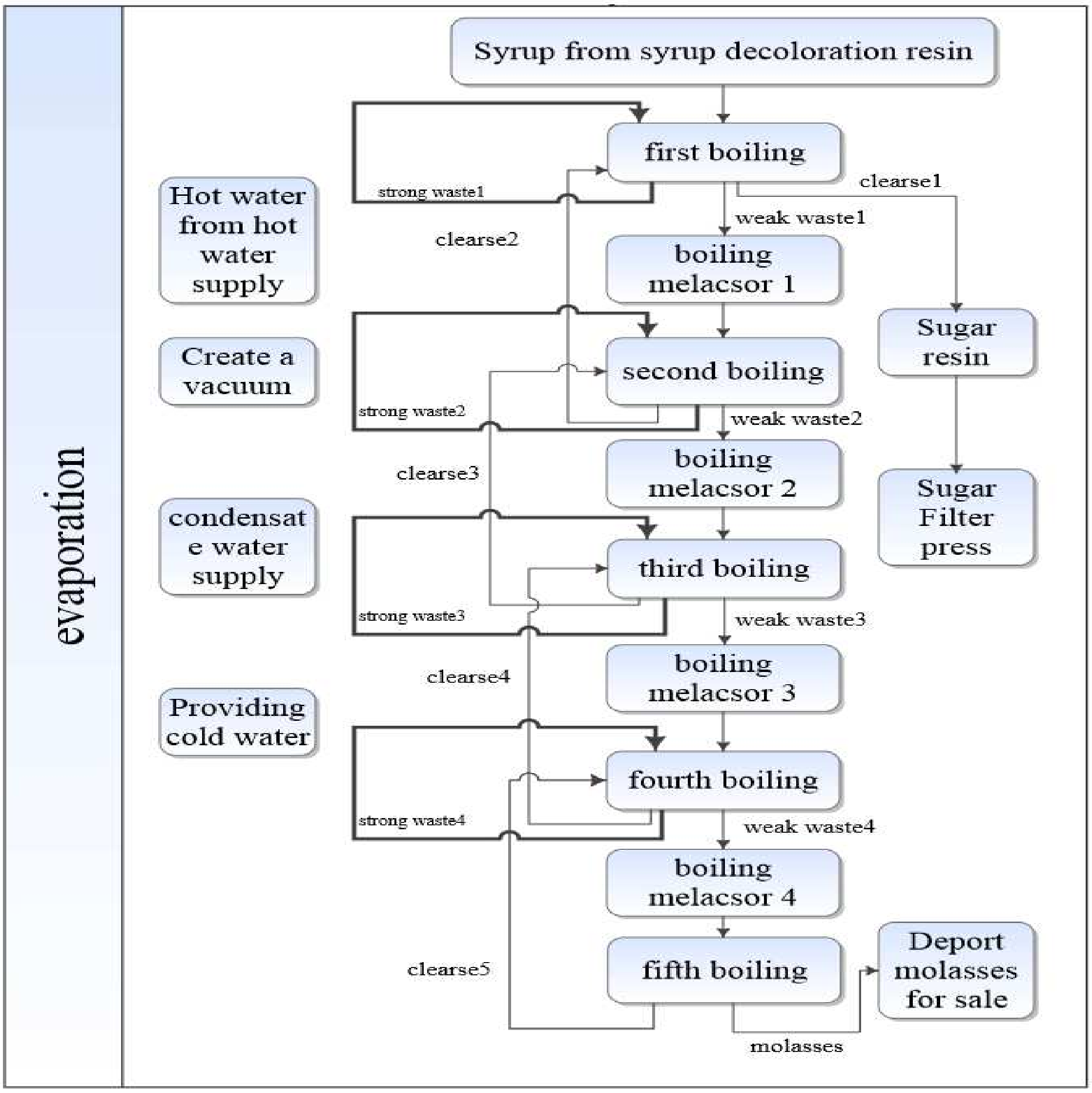

Figure8. The lowest level of decomposition (the process steps for evaporation are shown by an IDEF process map)

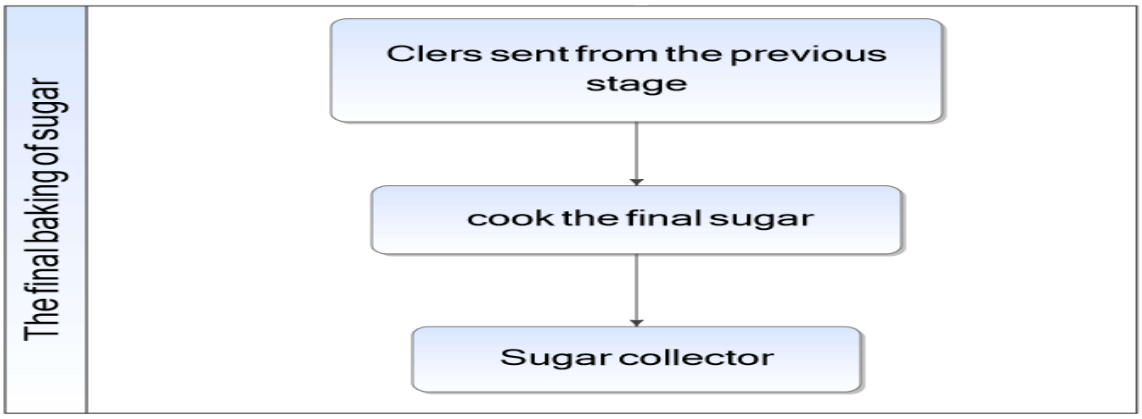

Figure9. IDEF process map of the lowest level of decomposition; the final baking of sugar

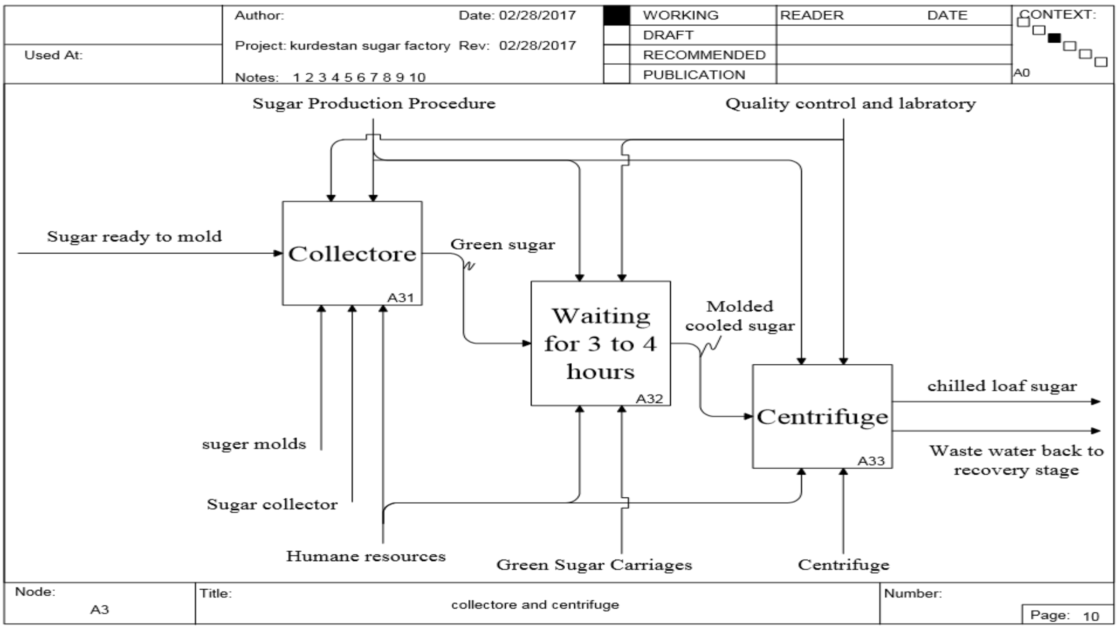

Figure10. Decomposition of box A3; collectore and centrifuge

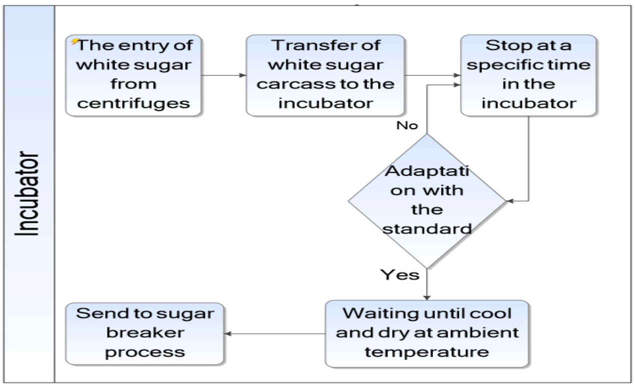

Figure11. IDEF process map of the lowest level of decomposition; Incubator

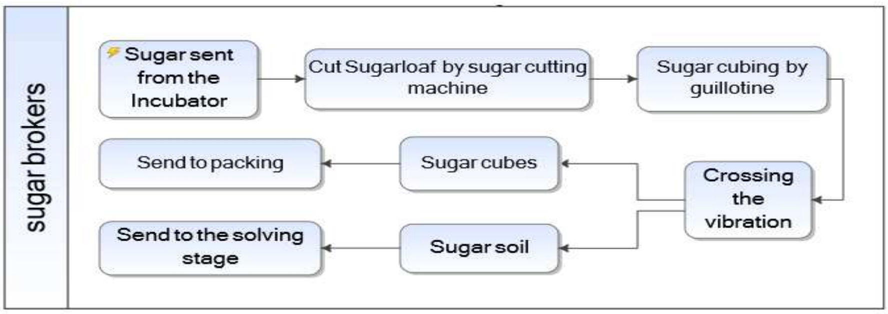

Figure12. IDEF process map of the lowest level of decomposition; sugar brokers

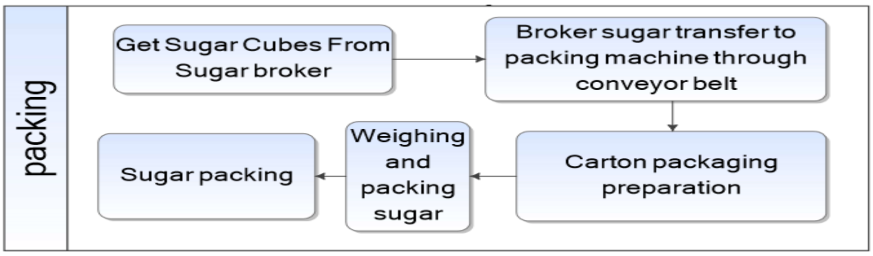

Figure13. IDEF process map of the lowest level of decomposition; packing

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.

Table2. Failures identified in the production process after drawing up the process map

Subprocess	Potential Failure	Failure Code
Solving	Brix higher than 60	F1
	Brix lower than 57	F2
	Low volume of syrup relative to the desired volume	F3
	High volume of syrup relative to the desired volume	F4
Lime saps production	low production of Lime Sap	F5
	Inappropriate quality of Lime Sap produced	F6
Lime Syrup (Defecation)	Not having a bowl in the range of 12 to 15	F7
	A negative effect on PH saturation stage	F8
Carbon dioxide production	The shortage of gas produced in steam boilers	F9
	Transfer of low carbon to syrup	F10
	Transfer high carbon gas to syrup	F11
Saturation	PH higher than 8.6	F12
	PH lower than 8.3	F13
Purification by Grant Pont	The syrup is not broken	F14
	Brix higher than 51	F15
	Brix lower than 49	F16
Filter press	it is not Correctly press filter and high $CACO_3$ at the output	F17
Syrup decoloring	Inappropriate decoloring of resin	F18
Vapor production	The steam generated is not enough.	F19
Syrup concentration	Vacuum shortage	F20
	Adding sugar powder in Brix less than 89	F21

	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
Sewage	Incomplete separation of syrup	F26
sugar preparation	Baking to a sugar-free stage with a temperature of fewerthan 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
Centrifuge	Failure to match the speed and centrifuge time with the product of the refereeing process	F32
Greenhouse (stove)	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
Sugar breaker	Inappropriateplacement 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
Packaging & Delivery	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.

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