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# Analyzing Manufacturing Process Knowledge Flows with KoFI

Oscar M. Rodríguez-Elias[1], Alberto L. Morán[2], Jaqueline I. Lavandera[3], Aurora Vizcaino[4]
[1]*UNISON-Mathematics Department, Hermosillo, Son., Mexico*
[2]*UABC-Facultad de Ciencias, Ensenada, B.C. Mexico*
[3]*FAMOSA-Ensenada, Ensenada, B.C., Mexico*
[4]*ALARCOS Research Group, Information Systems and Technologies Department, UCLM. Spain*
*omrodriguez@ciencias.uson.mx; alberto_moran@uabc.mx; jilavmac@efemsa.com; aurora.vizcino@uclm.es*

## Abstract

*This paper presents the use of the Knowledge Flow Identification (KoFI) methodology as a means to improve a manufacturing process knowledge flow. KoFI was initially developed to analyze software processes. In this paper we illustrate how it can also be used in a manufacturing domain. The results of the application of KoFI are also presented, which include some lessons learned, and the design of a knowledge portal together with the results of an initial evaluation from the potential users of this portal.*

## 1. Introduction

Knowledge is currently one of the most important organizational resources [2]. It is therefore important for organizations to search for ways to manage it. To accomplish this, knowledge management systems (KMSs) must facilitate knowledge workers with the knowledge they require from where it is created or stored, or capture and store knowledge to make it available for future use. It is necessary to understand how knowledge is flowing in the work processes, in this way it should be easier to identify the problems affecting that flow and, as a consequence, to propose possible solutions to improve the flow [5].

In this paper, we illustrate the manner in which the KnOwledge Flow Identification (KoFI) methodology [8] was used to analyze a manufacturing process, in order to improve its knowledge flow. The main reason for engaging in this study was to assist a manufacturing organization in two main aspects: 1) to improve the training of highly competitive personnel, and 2) to promote organizational learning. The main concern was to develop a KM system to assists the human resources training process, by making useful information and resources available to the employees to promote self-learning and knowledge diffusion.

In the accomplishment of the above goals, certain questions arose, such as: what knowledge is it important for the employees to have? Where does that knowledge reside? How can it be accessed? Which apects of such knowledge are being stored and where? Which are not being stored and why not? etc. To obtain initial answers to these questions and to propose a possible solution for the organization a study was carried out. In this study one of the organization's processes was analyzed using the KoFI methodology. The main results of this study are described here. The paper is organized as follows: Section Two summarizes the KoFI methodology. Section Three goes on to depict the analysis of the manufacturing process, while Section Four introduces a knowledge portal whose design was based on the results of such an analysis. Finally, Section Five presents the results of an initial evaluation of this portal, while Section Six concludes the paper.

## 2. The KoFI methodology

KoFI is a methodology focused on identifying and analyzing knowledge flows in work processes, following process engineering techniques [8]. It was defined to assist in three main areas: 1) to identify, structure, and classify the knowledge base of a studied process, 2) to identify the technological infrastructure that supports the process and which affects the knowledge flow, and 3) to identify requirements to improve the knowledge flow in the process.

In order to apply KoFI, it is necessary to define the specific process to be analyzed, and then model it. The process models are later analyzed following a four step process, as is shown in Figure 1. The process followed

is iterative, since each stage may provide information useful for the preceeding and successive stages. Thus, it is possible for the process model to evolve while it is being analyzed through KoFI. We shall now attempt to describe how each stage is carried out.

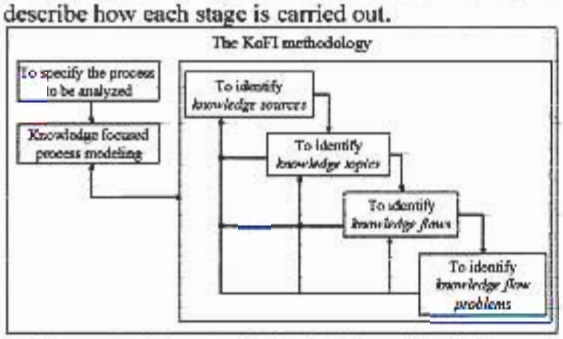


**Figure 1: Stages of the KoFI methodology.**

## 2.1. Knowledge focused process modeling

To model the knowledge involved in a process, it is convenient to use a Process Modeling Language (PML) which provides explicit representation of issues such as the knowledge consumed or generated in activities, the knowledge required by the roles participating in those activities, the sources of that knowledge, or knowledge dependencies [1]. In our study we used an adaptation of a highly used and flexible PML proposed in [7].

Since the focus of this paper is not on the modeling languages, we will limit ourselves to simply presenting the main activities carried out in KoFI.

## 2.2. Identification of knowledge sources and topics

These two steps focus on identifying the main documents and people involved in the process, that is, the main knowledge sources, and the knowledge that can be obtained form the, or the one required to accomplish the process' activities. We consider people as a knowledge source since they are the main source of tacit knowledge in a company. It is important that the identified sources and topics be organized and classified, for instance, by means of a taxonomy or an ontology in which the relationships between the elements of the process be represented. In fact, defining taxonomies is one of the first steps in the development of KMSs [6].

## 2.3. Identification of knowledge flows

In the third step we analyze how knowledge and sources are involved in the activities performed in the process. The main activities of the processes have, of course, been previously identified. Therefore, the process models help to analyze how knowledge flows through the process while the people involved perform their activities. Examples of this include knowing which sources are consulted, or which documents are generated while activities are performed. It is important to identify knowledge flows in activities and/or in sources. One example of this might be the transfer of knowledge from a person to a document.

## 2.4. Identification of knowledge flow problems

The knowledge flows identified in the previous stage are analyzed to discover problems which might be affecting them, such as whether the information generated from the activities is not captured, or whether there are sources that might help in the performance of certain activities, but which are not consulted by the people in charge of them. To do this, KoFI proposes the use of *problem scenarios*, which are stories describing the way in which a problem occurs [8]. These stories must particularly show how the detected problems affect the knowledge flow. Once the problem scenario is described, one or more alternative scenarios must be defined to illustrate possible solutions, and the manner in which those alternative solutions may improve the flow of knowledge.

# 3. Analysis of the manufacturing process

The KOFI methodology was used in a manufacturing process with the goal of detecting how this process could be improved from a knowledge management point of view. The study was conducted in a Mexican industrial company dedicated to the manufacturing of cans. We studied one of eight processes performed in one of nine departments in one unit of the company, specifically the process in charge of transforming the aluminum rolls into the first versions of the cans (known as the "Formation area"). Forty one people were involved in this process.

It is important to highlight that the company has documented all its processes, and follows standards for documenting almost all its activities. Moreover it has an ISO9001-2000 certification, so it was not necessary to develop detailed models of the processes. We simply focused on developing high level models to identify the main knowledge required for the central activities of the processes and to identify the main knowledge and information sources involved.

The data used to analyze the process was captured through interviews, and by analyzing documents and

information systems. Nineteen employees were interviewed by using the long interview technique, but adjusting the interviews to the following format: the general data of those interviewed, the main activities performed, and knowledge sources known by them, and their level of knowledge of the process. The duration of the interviews ranged, from 30 minutes to 2 hours, depending on the level of responsibility of those interviewed. A total of 119 documents and systems were also analyzed, of which 24 were discarded because they were duplicated.

### 3.1. Results of the analysis

The main results of the analysis of the process were classification schemas for knowledge sources and topics, which were later used as a basis for structuring a knowledge map from which a knowledge portal was developed. Additionally, the knowledge flow analysis phase helped us to identify the relationships between the various knowledge sources and topics, and the activities carried out in the process. These main results are next described.

**3.1.1. Knowledge sources**. The identified sources were very diverse, from process documentation to organizational norms. These were classified into: 1) documents, including three subcategories: process, technical, and organizational documentation; 2) information systems, including two subcategories: query, and transactional systems; 3) people, including four subcategories: staff, specialists, external clients, and internal clients; and 4) others, including two subcategories: problems analysis, and simulation tools.

**3.1.2. Knowledge topics**. The identified knowledge topics were also very diverse, ranging from organizational behavior to special machine maintenance. These topics were classified in three categories: 1) product line activities, including product quality, machine maintenance, operation, and information technology (IT) application; 2) organizational culture, including knowledge of the company; and 3) general knowledge, including resource management, IT management, personnel management, and other individual knowledge.

**3.1.3. Knowledge flows.** In this step we modeled the knowledge required in each activity of the process, the knowledge that each role required to perform these activities, and the knowledge sources consulted or generated in each activity, following an adaptation of the Rich Picture [4] technique proposed in [7]. These models helped us to identify the relationships between the knowledge sources and topics, and the activities of the process. This allowed us to create a knowledge map by defining the knowledge that might be obtained from each source, and by defining the activities in which the sources or the knowledge were being used or generated.

**3.1.4. Knowledge flow problems**. In the final step of KoFI, we identified two main areas of opportunity. First, it was observed that some areas of the process were not well supported with documentation. For instance, there was not enough documented information on the use of certain mechanical and electrical tools; therefore, that knowledge resided only in people's experience. An additional problem was the identification of important knowledge sources that were not being used; for instance, the company had some simulation tools that were not being used.

Based on the information obtained by applying the four steps of the analysis phase of KoFI, we decided to develop a knowledge portal which could facilitate access to the available knowledge sources , classifying them according to the activities in which they would be useful. It was also decided that the portal should provide access not only to documents, but also to other types of sources, such as information systems, or support tools, in order to promote the use of all the available types of knowledge sources of the company.

## 4. Designing the Knowledge Portal

From the analysis we created a knowledge meta-model which could be replicated to any area of the organization while achieving the same results.

### 4.1. Meta-model

The proposed meta-model, represented in Figure 2, comprises the knowledge types and sources involved in the knowledge generation and acquisition process.

In this meta-model the knowledge concepts are integrated with the knowledge topics and sources. The knowledge concepts are required, generated or modified by the activities within the study area, which are described as work definitions. In turn, these work definitions can be represented as processes, activities or decisions. Each knowledge concept/source association contains information about the knowledge level it requires. Finally, the available format and location for consulting each source are specified.

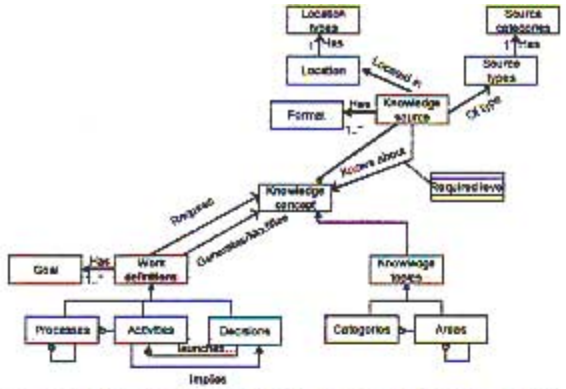


**Figure 2: Meta-model of knowledge types and sources.**

## 4.2 Knowledge portal structure

This meta model was used as a base to design the structure for a knowledge portal. Figure 3 shows the resulting general structure of the portal. This structure comprises a first level in which initial interfaces (pages) are accessible (e.g. home and registration pages). The second and third levels are pages which correspond to the manufacturing areas and sub-areas of the organization, respectively, according to the rich picture models developed during the analysis. The fourth level corresponds to pages on the processes that integrate each of the sub-areas identified from the involved knowledge flows. Finally, the fifth level presents all the identified knowledge sources for the specific process of the sub-area. This structure is representative of all and each of the manufacturing sub-areas, as identified during the analysis.

## 4.3 Knowledge portal UI design

The design of presentation and navigational features of the user interfaces (pages) of the knowledge portal also emerged from insights identified in the analysis and initial phases of design.

These include information about the identified knowledge flows, the main sub-areas of the organization, and the structure of the portal previously identified, which resulted in the options included in the menus and main layout sections of the pages. These allow users to find the required information by simply identifying the specific area in which information is generated or required, and following the resulting navigational structure (area → sub-area → process) to locate the specific knowledge source, instead of just alphabetically (or randomly) browsing through the information.

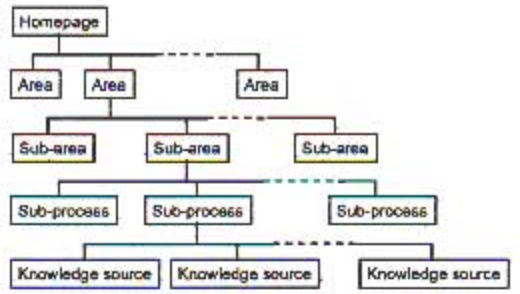


**Figure 3: General structure of the Knowledge Portal.**

Figure 4 depicts an example of the layout and content of a page from the current prototype for the "Formation" area.

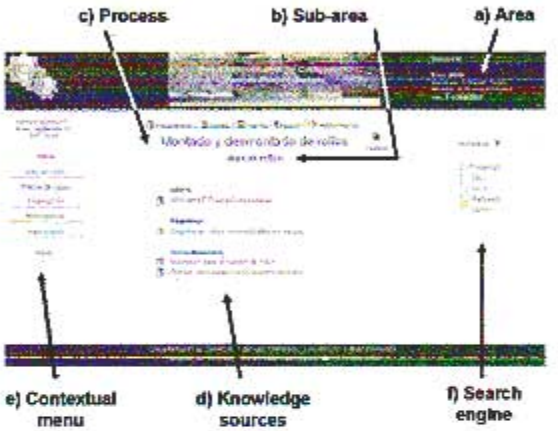


**Figure 4: Example of the page contents and layout of the Knowledge Portal.**

The information provided includes the name of the manufacturing area being consulted (4.a), the name of the specific sub-area (4.b), the name of the selected process within the sub-area (4.c), and most importantly, links to knowledge sources (and types) available for that process (4.d).

Additionally, the page includes a "contextual" sub-area menu to facilitate navigation through the information (4.e), which is always available while the user stays in that particular sub-area of the portal. Also, it includes a search engine (4.f) which allows a search to be performed by simply specifying a keyword on the required topic, and optionally, the "places" in which the information should be searched for.

The interface in Figure 4 represents the final destination for users looking for a particular knowledge source who, by following only three links

(area → sub-area → process), arrive at the knowledge sources (either documents, systems or people) required to perform their intended activities.

Finally, this design adheres to the organization's established standard guidelines for this kind of applications.

## 5. Preliminary Evaluation of the knowledge portal

We conducted a preliminary evaluation in one of the production areas to both determine the impact and acceptance level of the users on the system, and to provide support for the decision-making process concerned with the continuation of the system's implementation in other areas of the organization. The evaluation considered aspects concerning perception of usefulness and ease of use [11].

The evaluation consisted of 1) an introductory session, in which the system was presented to the users and its functionality was demonstrated to them. This included examples on how to search for and retrieve knowledge sources by means of navigating through areas, sub-areas and processes, as well as through the search engine; and 2) the application of a questionnaire containing 12 questions referring to perception of usefulness (6) and ease of use (6). Each evaluation session (induction and application of the questionnaire) was done in approximately one hour.

The subjects of the study were 41 employees of the "Formation" area for which the prototype was developed. The subjects included leader mechanics, process mechanics, operators and process engineers, whose participation was voluntary. The sample was divided into 4 groups according to the natural operative processes (3 groups of ten people and 1 of eleven). The application process of the evaluation was completed in three days.

### 5.1 Analysis and discussion of evaluation results

The subjects had positive appreciations with regard to the knowledge portal, as is reflected in their answers in the questionnaire. Table 1 shows the answers to the questions about the perception of usefulness of the tool. The users perceived that the portal would allow them to increase their productivity and to perform their tasks more easily (82.93% "Agree" in both cases), although some of them had doubts regarding the fact that this would increase their productivity (24.39% "Have Doubts"). Only one person (2.44%) "Disagreed" that the tool would help him/her to complete his/her tasks faster.

**Table 1: Perception of Usefulness.**

| Question | Agree (%) | Have Doubts (%) | Disagree (%) |
|---|---|---|---|
| Complete the task faster | 78.05 | 19.51 | 2.44 |
| Increase task performance | 82.93 | 17.07 | 0.0 |
| Increase productivity | 75.61 | 24.39 | 0.0 |
| Improve efficiency | 80.49 | 19.51 | 0.0 |
| Ease the task | 82.93 | 17.07 | 0.0 |
| Is useful | 87.80 | 12.20 | 0.0. |

**Table 2: Perception of Easy of Use.**

| Question | Agree (%) | Have Doubts (%) | Disagree (%) |
|---|---|---|---|
| Learning to browse | 85.37 | 14.63 | 0.0 |
| Finding information | 60.98 | 39.02 | 0.0 |
| Clear user interfaces | 65.85 | 34.15 | 0.0 |
| Flexible interaction | 65.85 | 34.15 | 0.0 |
| Becoming an expert | 53.66 | 46.34 | 0.0 |
| Is easy to use | 68.29 | 31.71 | 0.0. |

Table 2 shows the answers to the questions about the perception of ease of use. As can be seen, although most of the users perceived that it was easy to learn to browse through the information (85.37% "Agree"), some had doubts concerning the ease of finding information (39.02% "Have Doubts"), and even more users had doubts concerning becoming experts on the use of the tool (46.34% "Have Doubts"). A possible explanation could be that a little more than a third of the users had doubts concerning the clarity of the presented interfaces, as well as about the interaction flexibility that these provide (34.15% in both cases).

In general, most of the users considered the knowledge portal as a useful (87.80% "Agree" – Table 1) and easy to use tool (68.29% "Agree" – Table 2) for the accomplishment of their work.

## 6. Discussion and concluding remarks

Integrating KM into work processes is one of the main concerns in the KM community [9]. Several works related to the integration of KM into work processes can be found in the relevant literature (e.g. [1, 3, 10]). Most of the approaches we have found are either orientated towards developing specific KM

systems, or require special tools or PMI.s for their use. Before proposing a specific approach for managing knowledge in an organization, it is important to analyze the organizations' work processes from a knowledge flow perspective [5], since supporting knowledge flow should be the main focus of KM. The main contribution of the present work is the use of an approach which takes this observation into consideration. We have illustrated how the KoFI methodology [8] may be useful for proposing means to improve the knowledge flow in a manufacturing company. This should be accomplished not only by developing new systems, changing organizational culture, and so on, but also by integrating the current infrastructure and the real work being done by the people in charge of the organizational processes.

The main result of the study was illustrating the usefulness of the KoFI methodology in a manufacturing setting; particularly for the design of a knowledge portal based on the real work structure of a company. The portal integrates the knowledge sources available, and presents them to the users by following an organizational structure which emerges from the application of the different steps proposed by KoFI. Even though more research is required to evaluate if the portal will allow the company to improve the training of highly competitive personnel, and to promote organizational learning, the preliminary evaluation of this portal has led us to believe that it could help to accomplish this, since such a portal was considered to be highly useful and used by the employees of the company. As future work, we are planning to apply the KoFI methodology to the analysis of all the company's other processes, in order to extend the use of the portal to the entire organization. This should help us to continue evaluating the benefits and limitations of KoFI.

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