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Produce Field Instructions from  
Product & Process Models  
(FIPAPM) - Case Study & Guideline

By

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**CIFE Working Paper #WP111  
DECEMBER 2008**

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# **IMPLEMENTING A METHOD TO PRODUCE FIELD INSTRUCTIONS FROM PRODUCT AND PROCESS MODELS (FIPAPM) – CASE STUDY AND GUIDELINE**

Claudio Mourgues, John Kunz, and Martin Fischer

## **Abstract**

To address the challenges of producing good quality work instructions for construction laborers, the authors developed a method to produce Field Instructions from Product and Process Models (FIPAPM). However, implementing such a method in a contractor's organization presents implementation challenges and requires guidelines that help the contractor to make decisions about people and procedures to address the implementation barriers. Existing literature identifies several relevant implementation barriers and strategies but it is unknown how these barriers and strategies apply to the specific context of a method to produce good quality work instructions and, more broadly, of methods that integrate formal product information and construction knowledge.

This paper presents a case study where we implemented one of such methods, the FIPAPM method, on a cast-in-place concrete project. We use this study to identify which implementation barriers apply and to understand how they apply to the context of the FIPAPM method. Then, based on strategies to deal with these barriers, we present a guideline to help contractors to implement this method. This guideline identifies seven actors (top management, technology leader, process modeler, product modeler, construction expert group, field management, and laborers), their roles and the steps to implement the method.

The presented guideline is a particular case of guidelines for methods that integrate formal product information and construction knowledge, which will help to integrate

the work of designers, planners, and estimators with the work that laborers do in the field. The presented guideline will allow contractors to address the specific challenges of implementing the FIPAPM method. The guideline also enables researchers to perform more detailed implementation studies tracking the use of this guideline by a contractor to provide insights that will help refine the implementation guideline.

**Keywords:** Construction, product models, process models, work instructions, field information, implementation, guideline.

## **1. Introduction**

Producing good and formal work instructions for construction laborers is a challenge for field management personnel (i.e., superintendents, foremen). This process is time intensive, error-prone (as it requires integrating information from different informal sources), and it is prone to produce inconsistent outcomes as different people will likely produce instructions with different format and content.

In a related research effort (Mourgues et al., 2008), we developed and validated a method to automatically produce field instructions from product and process models (FIPAPM). Field instructions are work instructions that have a predefined format and content based on the field instructions template (Mourgues and Fischer, 2008). The FIPAPM method addresses the challenges described above by formalizing the information involved in producing field instructions. However, implementing such a method in a contractor's organization presents additional challenges and requires guidelines that help the contractor to make decisions about people and procedures to address the implementation barriers. Existing literature (e.g., Anumba and Ruikar, 2002; Stewart et al., 2002; Dossick and Sakagami, 2008; O'Brien, 2000; Williams et al., 2007; Peansupap and Walker, 2005; Stewart et al., 2004) identifies several implementation challenges and strategies for methods related with information

technologies. This literature addresses implementation from different angles: from strategic views of the implementation process in general to implementation case studies of specific technologies such as web-based project management and electronic commerce systems. However, it is unclear from this literature which of the challenges identified by the literature apply and how they apply to the particular context of a method to produce work instructions such as the FIPAPM method. This context includes the use of 3D building (product) and construction process models in a contractor organization to produce daily work instructions for construction laborers, the formalization of construction product and process information, and the participation of personnel at different levels of the company and with different cultural and knowledge backgrounds (e.g., field management personnel that produce field instructions, modelers that create product and process modelers, and laborers that use field instructions).

This paper presents a case study of the implementation of the FIPAPM method for a cast-in-place (CIP) concrete contractor. The paper describes this implementation process and its barriers, and discusses how these barriers relate to barriers found in the literature. The paper uses this discussion and the experience of the authors working in the field using the FIPAPM method to define an implementation guideline for the FIPAPM method.

Section 2 summarizes the findings of prior research on implementation barriers and strategies. We focus the review on implementations related to information and communication technologies (ICT) since the FIPAPM method uses product and process models to directly address field communication issues. Section 3 summarizes the motivation of producing work instructions and explains the main elements of the FIPAPM method. In Section 4, we describe and discuss the implementation case study, the results and their relation with the literature review findings. Based on this analysis, Section 5 presents the implementation guideline. Finally, Section 6 summarizes the conclusions of this work.

## 2. Findings from prior research

This section reviews literature on barriers and strategies of implementation of ICT, focusing on two comprehensive reviews of prior literature (Peansupap and Walker, 2005; Stewart et al., 2004) that provide a thorough overview of the domain.

Peansupap and Walker (2005) present a thorough review of the literature on ICT implementation issues. The actual barriers listed in their review are very varied as they come from studies with different purposes and methods. These findings are consistent with barriers found by other authors such as Anumba and Ruikar (2002), Stewart et al. (2002), Dossick and Sakagami (2008), O'Brien (2000), Williams et al. (2007), Al-Ghassani et al. (2006), and Marshall-Ponting and Aouad (2005). Peansupap and Walker classify the implementation barriers in four categories: technological, individual and social, managerial, and other. These categories are useful to structure the analysis of the barriers and the strategies to deal with them. Below, we extract a subset of their barriers that relates to the context of our research explained above.

- **Technological:** Lack of suitable IT infrastructure, data quality and reliability, and technology maturity.
- **Individual and social:** Low IT competence of field personnel, employee resistance, and lack of user involvement.
- **Managerial:** Change in work processes, top management support, duration of relationship among the implementation actors, need for role descriptions, technology leadership, lack of training, high work load.
- **Other:** industry fragmentation, language barriers.

Stewart et al. (2004) go beyond the identification of barriers as they also study the connection between a set of implementation barriers and strategies they obtained from a literature review. They group these barriers and strategies in three decision-making levels: industry, organization (i.e., company), and project levels. This grouping is very

useful for a contractor to assign the implementation resources. For the purpose of our research, we focus on the organization and project levels because that is where a single contractor can make changes to address the barriers. Table 1 shows a set of barriers and strategies that we extracted from Stewart et al. based on the context of our research.

Table 1. Implementation barriers and strategies from Stewart et al. (2004).

<b>Levels</b>	<b>Barriers</b>	<b>Strategies</b>
Organization	Resistance to change by staff; lack of IT strategic planning.	Develop an IT strategic plan with full support of senior management; encourage employees to embrace IT related applications; adopt IT related applications with short learning curves; use down time to train staff and upgrade their technologies.
Project	Tight project timeframes; low technology literacy of some participants; lack of IT leadership; fear of change and uncertainty.	Ensure adequate technical support is provided; setting strategic and technical direction; appoint a project IT champion; encourage more active involvement by IT staff.

There is, of course, overlap between the findings of Peansupap and Walker (2005) and Stewart et al. (2004), but nonetheless these findings represent a comprehensive list of barriers and strategies related with information and communication technologies. It is unclear, though, to what extent and how these barriers and strategies relate to the context of the FIPAPM method. In Section 4.5, we discuss this relation within the frame of the four barrier categories (i.e., technological, individual and social, managerial and other) and the two decision-making levels (i.e., organization and project) to make this discussion more useful for the decision makers (i.e., contractors).

### **3. FIPAPM background and description**

Our selection of barriers and strategies from the literature is based on the technologies and context involved in our research. To understand this context and the specifics of our implementation case study, the next two sections explain the motivation for and essential concepts of the FIPAPM method.

#### **3.1. Work instructions background**

The use of traditional verbal instructions to communicate design and construction information to construction laborers negatively affects the workforce questions, labor productivity, rework and safety on site (Mourgues and Fischer, 2008). The causes of these negative impacts are the poor quality of construction drawings (Gao et al., 2006; Makulsawatudom and Emsley, 2003; Kagan, 1985), poor verbal communication skills in construction (Makulsawatudom et al., 2004), and nonstandard work operations usually based on the foremen/superintendent's experience (Oglesby et al, 1989).

Mourgues and Fischer (2008) show that field personnel assess the use of more formal and better quality work instructions – which the authors call field instructions – more positively than the use of the informal verbal instructions. However, there is not much evidence of companies using formal work instructions in construction. The companies that create formal work instructions do so as part of the work packaging process (Kim and Ibbs, 1995). In this context, we use a production-oriented meaning of work package as defined by Choo et al. (1999): “work package defines a definite amount of similar work to be done (or a set of tasks) often in a well-defined area, using specific design information, material, labor, and equipment, and with prerequisite work completed.” Thus, companies put together the information workers need to perform the amount of work defined by the work package. However, this process is done on a case-by-case basis (without a formal format and content for those instructions) and it is usually done only for complex work packages because the state-of-practice method



to produce good quality work instructions is time intensive, error prone and unsystematic (i.e., produces instructions with inconsistent format and content).

To address the issues above, Mourgues et al. (2008) developed a method to produce field instructions from product and process models (FIPAPM). We briefly describe this method in the next section to provide context for our implementation case study.

### 3.2. FIPAPM description

Figure 1 depicts the production of field instructions using the FIPAPM method. All the information used by the FIPAPM method is formalized through information schemas. Thus, the method interprets the work scope of the activity that needs an instruction, and the design and construction information that controls the rapid, correct and consistent generation of that instruction based on a format and content template (field instructions template). Figure 2 shows an example of a field instruction.

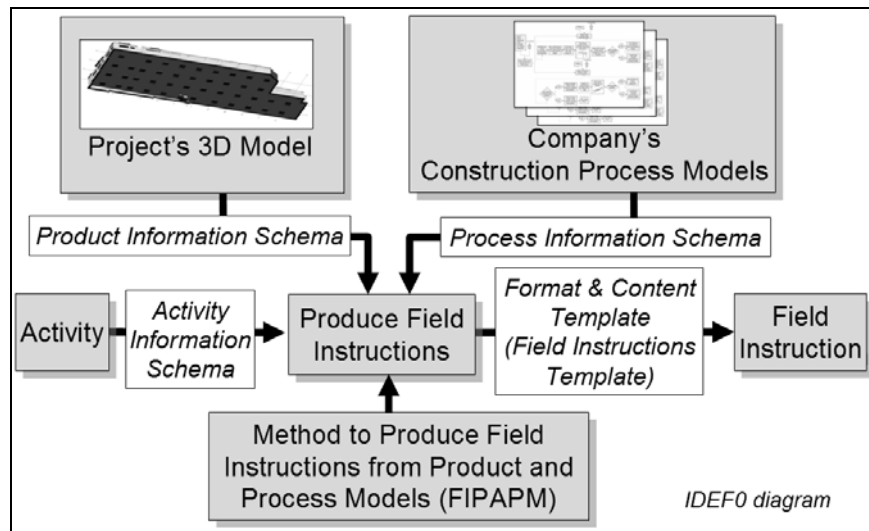


Figure 1. Production of field instructions using the FIPAPM method. This approach is based on the formalization of all the input and output information of the method. The figure follows the IDEF0 convention where the input information at the left (activity) changes for each use of the method while the control input information at the top (3D and process models) remain relatively constant.

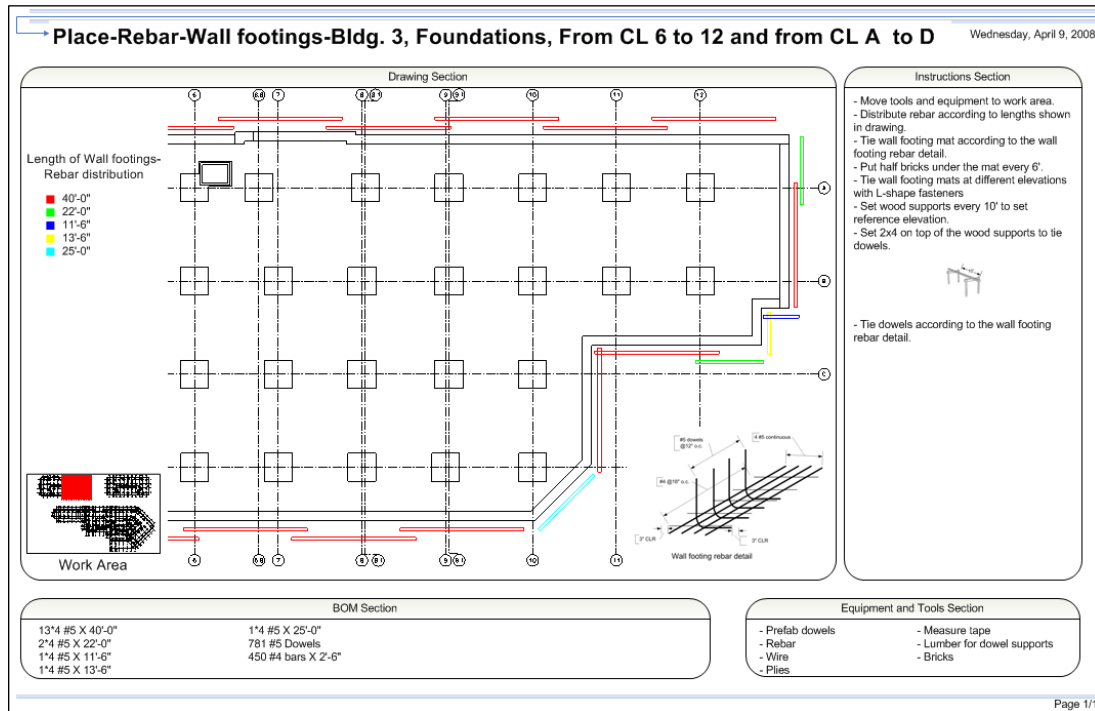


Figure 2. Field instruction example. A field instruction is the output information of the FIPAPM method (Figure 1). This instruction has a formal format and content defined by the field instructions template. There are 4 main sections that group all the information: drawings, instructions, equipment and tools, and bill of materials (BOM). The drawing section has 4 elements: model view, details view, color coding legend, and key plan.

There are four actors in the approach shown in Figure 1: **1) the user of the FIPAPM method** (Foreman/Superintendent/Project engineer), who produces a field instruction for each activity the laborers will work on. **2) The users of the field instructions** (laborers). **3) 3D modelers**, who produce the 3D model and related information for the project. This is done once at the beginning of the project and then updated during the construction phase. **4) Construction process experts**, who are a mix of office and field experts that together agree on the company's best practices (represented by process models). The modeling of the company's best practices is done periodically (e.g., every six months) as new methods, equipment, regulations, etc., become relevant.

The user of the FIPAPM method, based on the selected activity, selects the data s/he needs from the 3D model and construction process model, extracts the information from that selection, and organizes it in the four sections of the field instructions template.

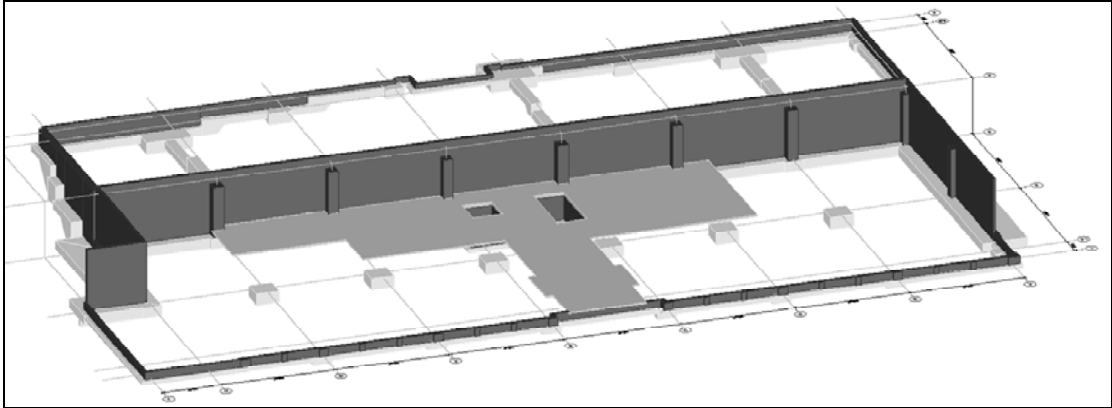
#### **4. Implementation case study**

The main purpose of this case study was to explore implementation barriers specific to the FIPAPM method and, based on their analysis against the general barriers and strategies provided by the literature review, define an implementation guideline for the FIPAPM method.

Since Mourgues et al. (2008) developed the FIPAPM method within the CIP concrete domain, we implemented this method with a CIP concrete contractor that performs digging, reinforcing, and concreting operations. The next sections describe the specifics of the project (people, infrastructure, information flows, etc.) and the implementation process, followed by a discussion of our findings in this case.

##### **4.1. The project**

The implementation case study consists of the CIP concrete foundations, slab-on-grade and retention walls for a mixed used building. Figure 3 shows a snapshot of the project's 3D model. This model was initially done by the contractor's designer as the base to prepare lift drawings.



*Figure 3. Snapshot of the project's 3D model. The figure shows the footings, retention walls, slab on grade, and column lines of the project.*

The contractor did not have office infrastructure in this project so the contractor's superintendent did his office job from his truck, where he had all the work documents (e.g., invoices, daily reports, change orders, RFI) and a laptop with internet connection over a PC card.

The project was run – from the contractor's perspective – by one superintendent and three foremen. Two foremen managed around 10 laborers each (the actual labor quantity changed every day) and the third foreman managed 3 laborers. The project was supported by a team from the main office composed of a project manager (who visited the project every two weeks), a designer, and clerks.

The information related to the work done in the field (i.e., activities, weather, problems, main resources) was recorded – to keep the main office informed – in daily reports made by the project manager who obtained the information verbally from the superintendent. These reports lacked detailed design information that describes the actual dimensions, locations, and construction details used for the work. They also lacked detailed construction information that describes the construction steps, equipment and tools and amount of materials used on that work. Other information flows were recorded in RFIs (requests for information), change orders, material use forms, and invoices, besides the traditional verbal information flows.

## 4.2. The implementation

Field and practical considerations (such as time frame of the project, contractor's agenda, physical and IT infrastructure available on the project, and design and field management manpower) forced us to take a more active participation and reduce the contractor's involvement in some of the implementation steps. Figure 4 depicts the implementation process and the different actors for each step of this process.

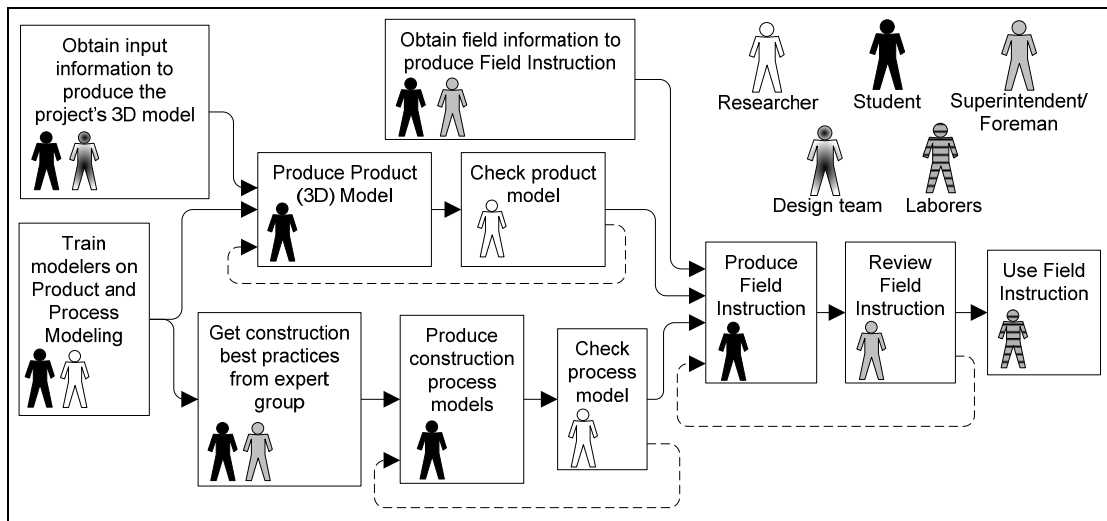
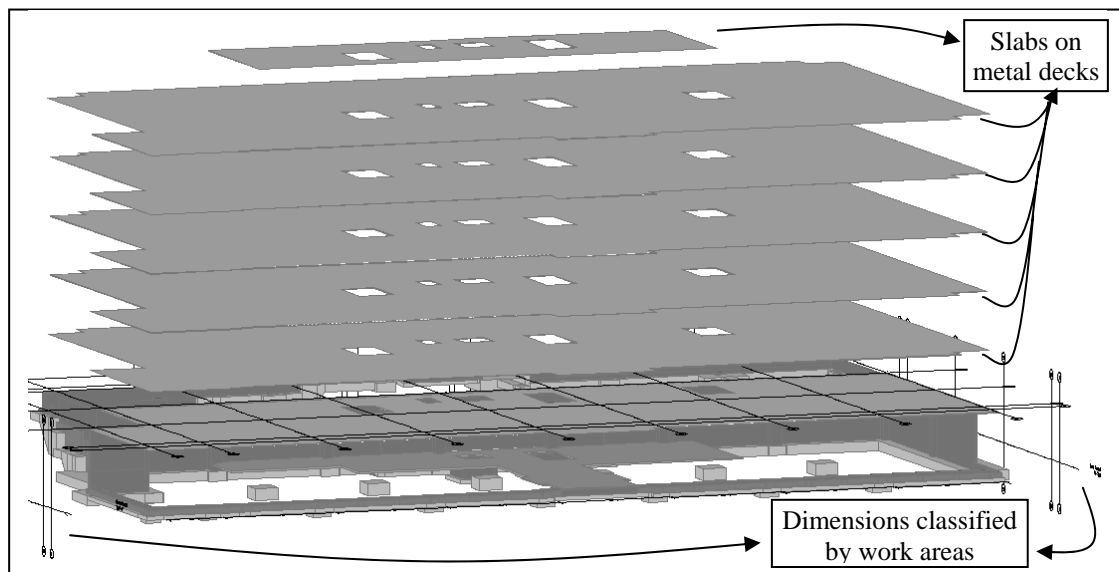


Figure 4. Implementation process of the FIPAPM method on the case study.

We worked with a graduate student from a project-based class to implement the FIPAPM method. The student played the roles of product and process modeler and field instruction generator. He interacted with the contractor's experts to build the process models according to the experts' construction knowledge. However, due to the changing conditions on the project and incompatible agendas of some actors, the main researcher played the role of the student at certain points of this implementation process.

The student and the main researcher spent one week on the project plus two weeks before the project visit preparing the 3D model, gathering construction process information, and working on the implementation logistics. The main implementation

activities in Figure 4 are the production of the 3D model, construction process models, and field instructions. The student modified the 3D model shown in Figure 3 to make it useful for the FIPAPM method. Part of this work was done before visiting the project but the final revisions were done in the project to include the “as is” information. Figure 5 shows the final 3D model after the review with the main researcher. The production of process models had to be done in the field because of the project uncertainties and the failure on obtaining the needed information through phone conversations. Finally, the student had two options to produce field instructions: the preferred option was to use a computer prototype we had developed for a previous research, and the second one was to manually follow the FIPAPM method in case the prototype did not work for the particular project conditions.



*Figure 5. Snapshot of the project’s 3D model created by the student and researchers. Compared with the 3D model in figure 3, this model is more complete as it includes building elements that are needed for the contractor’s activities (e.g., slabs on metal decks of the upper floors are needed for placing the wire mesh and pouring the concrete on those floors), more up-to-date (e.g., includes dimensions that were changed in the field), and more suitable for producing field instructions (e.g., dimensions and annotations are classified by work areas).*

### 4.3. Documentation of the implementation

To document the implementation case study, we gathered a set of implementation process and output metrics during the implementation. We defined these metrics to support the identification of implementation problems. We do not suggest that these are the metrics that a contractor that is implementing the FIPAPM method should use (we discuss those metrics in Section 5.1.). Below, we describe these documentation metrics and discuss the data gathering.

- **Time to produce product (3D) models (man-hours of modeling):** this metric is relative, of course, to the project's characteristics (size and complexity), the modeler's skills and experience, and the model's purpose (as it usually has more than one purpose, e.g., marketing, quantity take-off, constructability analysis and generation of field instructions). We used time cards to gather this metric.
- **Time to produce construction process models (man-hours of modeling):** analogously to the previous metric, this metric is relative to the complexity of the construction process being modeled and the modeler's skills and experience. We also used time cards to gather this metric.
- **Number of implementation process breakdowns (per source):** whenever something did not work as expected in the implementation process, we identified the event as a breakdown. We counted the breakdowns identifying the source, i.e., where in the implementation process the breakdown occurred. We used the steps of the implementation process described in Figure 4 as potential sources for breakdowns.
- **Information needs:** we collected the information that different actors needed during the main steps of the implementation process, whether this information was available at that time or not.
- **Output correctness:** this metric assesses how correct the final output (field instruction) and intermediate outputs (product and process models) were. We measured the correctness through a subjective assessment by the users of that

output (based on the steps in Figure 4). Field management personnel (superintendent/foreman) and laborers evaluated the field instructions while the researcher evaluated the product and process models.

- **Output schedule conformance:** this metric assesses how timely the final output (field instruction) and intermediate outputs (product and process models) were produced.

#### **4.4. Results and discussion**

Both modeling times were short: 7 hours and 20 minutes for the product model (3D model in Figure 5), and 15 minutes for the process model. The reason for the extremely short process modeling time is that we decided – early in the implementation – to extract the construction steps for each activity at the moment of producing the respective instruction instead of modeling the generic process model and then customizing it for the activity. We decided this because of time constraints and breakdowns during the process modeling step (explained below). The short product modeling time is because we had an existing 3D model to work with so we did not start from scratch.

We experienced several breakdowns during the implementation case study (Table 2). Most of the breakdowns occurred when obtaining information to produce the models or the instructions. These breakdowns reflect inefficiencies in certain work processes (e.g., making design information available to the field) and the lack of training and commitment of certain actors. The breakdowns of accessing the construction information led us to decide not to create the generic process models but to obtain the construction steps for each activity as needed as explained before. These problems are not surprising as there was no major preparation of the contractor for this implementation study. Another observation is that the breakdowns that occurred when producing the models or the instructions are mostly related with technical problems such as the computer prototype and the infrastructure at the jobsite.



Table 2. Breakdowns in the implementation process. For each breakdown category, the table shows where the breakdown happened in the implementation process, the number of occurrences (#) during the implementation, and some examples.

<b>Breakdown Category</b>	<b>Where in the implementation process</b>	<b>#</b>	<b>Examples</b>
Quality of design information	Produce product (3D) model	1	Drawings with incomplete and out-of-date information
Access to design information	Obtain information to produce 3D model	5	Drawings in the main office had not been digitized and put in the project's server; password of project's server was not available; difficulty extracting "as is" information in the field; missing drawings
Access to construction information	Get construction best practices from experts	2	Field construction experts could not abstract their knowledge; field construction experts were reluctant to share their knowledge
Process modeling skills	Produce construction process models	1	Student had difficulties obtaining the right information from the field personnel
Technology maturity	Produce field instructions	1	Computer prototype did not include some mechanisms necessary to produce field instructions for the particular activities happening in the project
Infrastructure	Produce field instructions	2	No printer with the needed specs available in the project; no office space

Field planning	Obtain field information to produce field instructions	1	Superintendent would not commit to activities for the next day
Lack of commitment	Review field instructions	1	Superintendent focused only on the drawing section of the field instructions

During the main steps of the implementation (i.e., produce 3D model, produce process model, and produce field instruction), we collected the information needs of the respective actors and the actions they took when that information was not available. The 3D modeler needed the information described below.

- **Drawings, existing 3D models (if any), and relevant specifications.** This is a must; the 3D modeler could not have done anything without this information.
- **Change orders that have affected the design.** We did not have access to the official change orders but we obtained this information from the contractor’s superintendent.
- **Confirmation of the drawing status (i.e., revisions).** The revisions and current version were not always very clear to the field personnel. So, it took us a couple of iterations between the main office and field contacts to get this information. When the information was not available, the modeler made assumptions to continue the modeling effort and then updated the 3D model as needed.
- **Relation between design information and work done in the field (“as is” information).** This information is related with the previous ones but even using the proper drawings and considering the relevant change orders, the work done in the field can differ from what was specified. Therefore, it is key to know the actual dimensions and locations of the built elements. The 3D modeler obtained most of this information by directly measuring the objects in the field. This task is much easier if the 3D model is updated daily by someone with easy access to field status and dimensions.

- **Names that are used for construction zones, objects, object subgroups, and resources.** This information has to be included in the 3D model as properties of the CAD elements to allow the generator of the field instruction to select the right design information in the 3D model.

The process modeler's scope reaches beyond the scope of the project because the FIPAPM method uses process models that represent the best practices of the contractor. This generic process model includes different potential scenarios that the contractor usually faces, many of which do not apply to a particular project. Then, the generator of the field instruction customizes this generic model for the specific conditions of the project. This generic modeling is best done out of the project's context but due to the constraints of the implementation process (time and people), we had to do it during the project. During the implementation process, the process modeler needed the information described below.

- **Potential scenarios that the contractor usually faces for a specific activity.** This information proved to be impossible to obtain from the superintendent. He was too involved in the specifics of the project. We decided to model only the scenario that applied to the current situation.
- **Construction steps for each scenario.** The superintendent knows this information very well but it was a challenge to obtain the information because his job priorities were on supporting his laborers and solving the ever present field emergencies.
- **Equipment and tools needed for the construction steps.** Once we had the construction steps, the related equipment and tools were easy to obtain.
- **Material quantities that laborers need to know to perform an activity.** The quantity take-off must be consistent with the way laborers use the materials. Assumptions made in office take-offs (e.g., the layout of wall formwork panels) sometimes were incorrect and needed to be verified and updated in the field.
- **Details needed (if any) for each construction step.** We got this information during the generation of the field instruction instead of during the process

modeling. This information delay occurred because it was easier for the superintendent to define the specific details that laborers need for an activity in a particular work area than for the same activity without a defined work area.

- **Color coding and content criteria for model view of the drawing section.** This information was also impossible to obtain during the process modeling. Both reluctance of the superintendent and time constraints forced us to define this information during the generation of the instructions.

Finally, the generator of field instructions needed the information described below.

- **Activities to be done the next day.** This defines what instructions need to be prepared. It was not always easy to get this information because the superintendent was reluctant to commit to a plan.
- **Specific work area where laborers will work.** Similarly to the activities for the next day, the superintendent was usually vague about the specific work area where the activities would happen. In some occasions, we assumed work areas that maximized the chances of including the actual work area.
- **Color coding and content of model view.** Once the work area of the activity was clear, the superintendent did not have problems defining what had to be included in the model view. The color coding was based on our suggestions.
- **Details needed for the drawing section.** Again, once the work area was clear, the superintendent knew very well what details were needed.
- **Last-minute modifications to the field instructions.** These are modifications or additions to the formal construction steps, drawings, equipment and tools, and materials to adjust them to particular conditions of the project that were not previously considered or had changed. This information is very dynamic so it was challenging to include it as we did not have a printer on site and we had to print the field instructions in advance.

- **Weather.** The weather affected the activities, the work area, and the specific considerations for construction steps. Thus, we had to continuously be aware of the weather forecast.

The implementation was partially successful as we produced good quality field instructions (based on the users' assessments) on time for the field operations but the generation of these instructions was ad-hoc and we could not use the computer prototype.

#### 4.5. Relation with literature findings

We found several implementation barriers in our case study that relate to what we found in the literature review. Table 3 summarizes the barriers organized by the dimensions found in the literature and specifies whether we found them in the case study and their importance for the implementation of the FIPAPM method.

Table 3. Summary of implementation barriers, their occurrence in the case study and their importance for the implementation of the FIPAPM method.

Dimension	Level		Implementation barrier	From literature?	Seen in the case study?	Importance
	Organization	Project				
Technological	O		Technology maturity	Yes	Yes	High
			Data quality and reliability	Yes	No	High
	P		Poor IT infrastructure	Yes	Yes	Medium
			Data quality and reliability	Yes	Yes	High
Individual and social	O		Resistance to change	Yes	No	High
	P		Low technology literacy	Yes	No	High
			Fear of change and uncertainty	Yes	Yes	High
			Knowledge abstraction	No	Yes	High

Managerial	O		Change of the work processes	Yes	No	High
			Need for role descriptions	Yes	No	Medium
			Technology leadership	Yes	No	High
			High workload	Yes	No	Low
	P		Tight project timeframes	Yes	Yes	Medium
Others	O		Industry fragmentation	Yes	No	Low

a) Technological

At the organization level, *technology maturity* was a big problem in our case study since our computer prototype included mechanisms only for certain situations and we did not have the time to make changes during the project. This forced us to manually follow the FIPAPM method to produce the field instructions. On the other hand, we did not have problems with the *data quality and reliability* that the FIPAPM method produced since we did a tight quality control of the output. However, this barrier can become a big problem as field management personnel take responsibility for this activity. Training, motivation, and quality control strategies can keep this problem under control.

At the project level, we found *poor IT infrastructure* to be a significant barrier. The lack of a proper printer and workspace delayed the production of field instructions and reduced the chances of including last minute changes. Another barrier was the *data quality and reliability*, this time considering the input data at the project level. The poor quality of design information hindered the product modeling effort. This barrier is project-specific (contrarily to the output data quality and reliability explained above) because the quality of the design information depends on the particular actors of the project.

b) Individual and social

At the organization level, we did not find too much *resistance to change* because of the short duration and the project focus of our case study. However, this is an

important barrier, featuring prominently in the literature, that will likely manifest itself more strongly on a larger scale implementation of the FIPAPM method as workers will perceive the change as something more permanent than the transitory experience of the case study. A good strategy to address this barrier is a clear IT strategic plan with incentives and training.

At the project level, *low technology literacy* did not play an important role in the case study as the researcher and the student interacted directly with the technology. However, this will become a very important barrier for a larger implementation where this interaction is done by the field management personnel. The superintendent could interact with the interface of the computer prototype to produce field instructions but making adjustments in the input information (i.e., product and process models), using the FIPAPM method manually, and solving technical problems (e.g., printing failures, file format incompatibilities) was beyond his skills. A strategy for this problem is to provide support from the main office and training for the field management personnel. Related with this barrier, *fear of change and uncertainty* was very clear during the case study. According to Zabelle and Ortiz (2005) – adapted from Larson (2003) –, the lack of the skills needed for a work method increases the anxiety or fear to adopt that method. Also, we observed uncertainty about people's value as the FIPAPM method captures the company's construction best practices and makes the communication of work instructions more a science than an art. This uncertainty became apparent through the field management's reluctance to share their knowledge. The company must address this barrier by creating a knowledge-sharing culture and emphasizing the importance of the field management as methods such as FIPAPM are intended to help them focus on value-adding activities. A barrier that we found in our case study but not in the literature is the *knowledge abstraction*. This means that it is hard for field management personnel to abstract their construction knowledge (i.e., take it out of the project's context) and also for process modelers to ask the right questions to help this abstraction process. A better strategy is to move the process modeling out of the project, bring the respected experts in the company together to brainstorm about the

construction operations, train the process modeler to facilitate this process, and consider the use of modeling consultants to support the initial modeling efforts. It is not surprising that this barrier is not found in the literature on the implementation of IT systems because the systems studied by those researchers were typical IT systems like e-commerce, web-based project management, wearable computers, wireless communication, and communication infrastructure, and did not include the implementation of complex, knowledge-based systems like the FIPAPM method. Artificial intelligence literature on expert systems (Kidd, 1987; Diaper, 1989; Hart, 1992) has identified this knowledge elicitation problem and provided methods to approach it. As construction companies formalize their work processes and knowledge more and more to create more powerful software applications this barrier will likely become a critical barrier to manage.

c) Managerial

At the organization level, the *change of the work processes* did not play a big role in the case study since we performed most of the implementation tasks. However this will likely become a big barrier when these tasks are performed by the contractor as the FIPAPM method requires introducing process modeling in the organization. That is a big change for construction companies, especially small contractors, but one that can also bring big benefits even out of the scope of the FIPAPM method as process modeling is key for knowledge management and training. To deal with this barrier, companies must clearly define and make it explicit to their workers how this change relates to the strategic plan of the company. Also, consultants can train and support the company in the process modeling efforts. Related to the previous barrier, the *need for role descriptions* was not evident in our case study as we performed many of the roles that will be the company's employees' responsibility. Similarly, *technology leadership* and *high workload* played minor roles in our case study because of our involvement. This situation will likely be different when companies implement the FIPAPM method by themselves. Companies must have a strategic plan that defines the roles including a technology leader. The workload barrier is a temporary concern that will be



compensated as the implementation of the FIPAPM method reduces the workload due to field communication, productivity, and quality problems. Another barrier from the literature is *top management support* and although this was not a problem in our case study, it is indeed a must for this kind of implementation.

At the project level, *tight project timeframes* heavily affected the involvement of field management in the implementation process. This can be addressed moving the process modeling out of the project and clearly defining the role of the implementation actors in the field.

d) Other

At the organization level, *industry fragmentation* was not a big barrier since the implementation process happened within the contractor's organization. The only impact of this barrier was on the access to design information. There is not too much that a contractor can do about this other than giving priority to design-build projects and creating strategic alliances that ease the access to information.

In the next section, we present an implementation guideline that addresses these barriers incorporating the strategies described above. This guideline also addresses barriers that we did not find in the case study (see Table 3) because, as explained above, we speculate that these barriers will have a medium-to-high importance in a contractor-led implementation of the FIPAPM method. The guideline explained below addresses the five elements for successful implementations – vision, skill, incentive, resources, and action plan – described by Zabelle and Ortiz (2005) (adapted from Larson, 2003).

## 5. Implementation guideline

From our discussion in the previous section and the main author's experience working with the FIPAPM method in the field, we found seven generic actors in the implementation process of the FIPAPM method: 1) top management, 2) technology leader, 3) process modeler, 4) product modeler, 5) construction expert group, 6) field management, and 7) laborers. These actors include and extend the four actors described in Section 3.2. Table 4 explains the roles for each of these actors.

Table 4. Actors and roles in the implementation process of the FIPAPM method.

<b>Actor</b>	<b>Role/Function</b>
Top management	Create incentives, choose technology leader, define strategic plan, and create a knowledge-sharing culture.
Technology leader	Manage the implementation process including ensuring that the proper IT infrastructure is in place, coordinating trainings, looking for external help (if needed), defining specific roles and functions for the implementation, and defining and tracking implementation success metrics.
Process modeler	Facilitate construction knowledge capture sessions and model the construction field processes. Process modeling can be an extra role of an existing professional such as an estimator or planner, or can be the function of a new employee.
Product modeler	Model the building facilities and keep these models updated on a daily basis. Product modeling can be part of the in-house design group of a contractor or can be a new function of field engineers.
Construction expert group	Provide construction knowledge during the knowledge capture sessions. This group is composed of field management personnel (project managers, superintendents and foremen) and office personnel whose work affects field work procedures (e.g., safety inspectors, estimators, equipment manager).

Field management	Use the FIPAPM method to produce field instructions for the laborers.
Laborers	Use field instructions for their work.

Figure 6 shows the steps to implement the FIPAPM method in a contractor’s organization. These steps are grouped by organization and project levels and depict the involvement of the seven actors described above. Sections 5.1 and 5.2 explain each step.

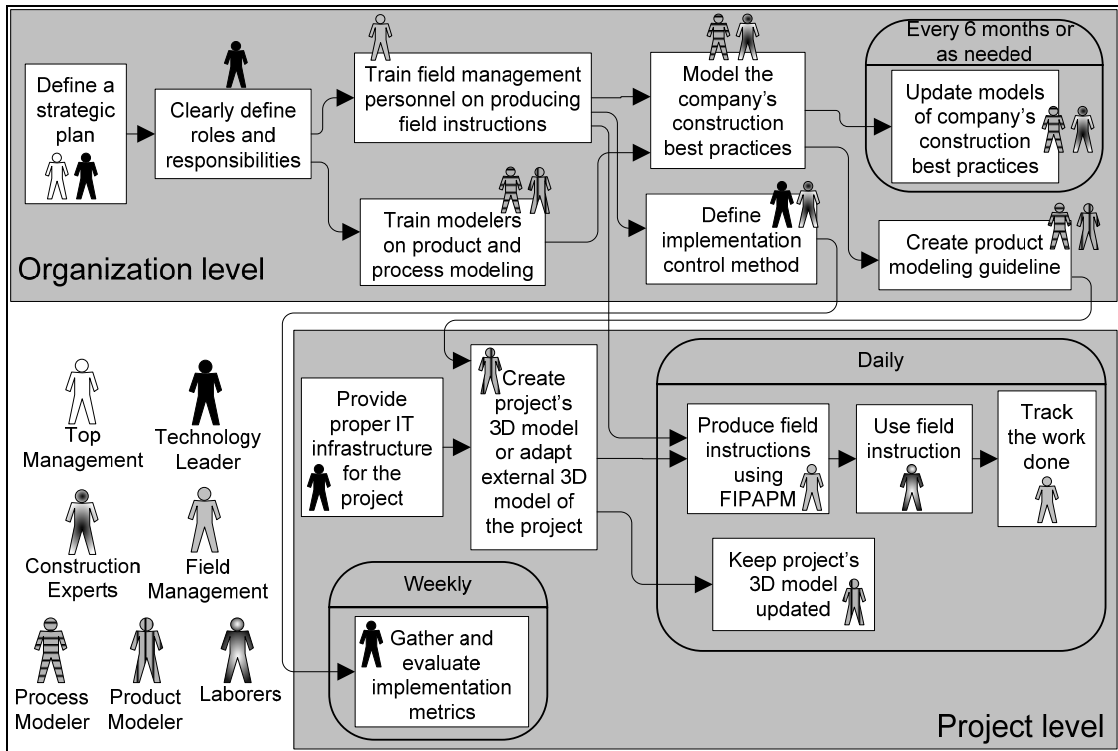


Figure 6. FIPAPM implementation guideline for a contractor’s organization.

### 5.1. Implementation steps at the organization (i.e., company) level

**Define a strategic plan:** The top management must define a plan coherent with the company’s business objectives. This plan must create a knowledge-sharing culture; define incentives – to address the resistance to and fear of change – for field

management, construction experts, and laborers to adopt the new method (FIPAPM); and define high-level goals regarding the implementation of the FIPAPM method such as cost and rework reductions. The technology leader assists the top management by providing the needed technical background about how the barriers identified in the previous section may apply to the company and what type of benefits may be expected.

**Clearly define roles and responsibilities:** Based on the strategic plan, the technology leader must clearly define the specific roles and responsibilities for the other actors in the implementation process including: who will provide what information to the modelers, what laborers will do when a field instruction is wrong or incomplete, who will train the modelers, who will be part of the group of construction experts, who will control and who will be responsible for the quality of information at different stages (e.g., product and process models, design information), how changes in the product and process information will be handled, and the documentation and metrics that will be collected and produced along the implementation process.

**Train field management personnel on producing field instructions:** Field management personnel must learn to produce field instructions using the FIPAPM method both manually and with a computer application (if available). It is important they learn to do it manually even though they will be using a computer application as they need to know what to do in case of a technology failure. Thus, besides learning a computer application that automates the FIPAPM method, field management personnel must learn the steps of the FIPAPM method and the software to review and extract information from product and process models (e.g., Autodesk AutoCAD and MS Visio). Field management personnel also need to understand the value of formal communication so they make efforts for keeping this formal communication when problems arise.

**Define implementation control method:** This step is motivated by the contractor's need to manage the implementation process proactively and not be limited by a particular implementation barrier. The technology leader must work with the construction experts (including the operations manager) to define the implementation metrics to be collected and the method to collect them (i.e., who and how). The purpose of these metrics is to evaluate how much and how well the method is being used by the company (i.e., use metrics) and what impact this use is having (i.e., impact metrics). From our experience, we recommend that the use metrics include at least: frequency and type of quality problems of the field instructions, number of instructions produced, time used to produce instructions, and percentage of company's work processes included in the company's process models. The impact metrics must include at least productivity but they could also include the number and types of workforce questions, rework and safety. These metrics must be consistent with the goals defined by the top management in the strategic plan. At least initially, it is important that the impact metrics track the activities that the field instructions support instead of broad or other activities (e.g., productivity of pouring concrete on wall footings instead pouring concrete in general) and, preferably, with the same work scope included in the field instructions (e.g., productivity of pouring concrete on wall footings of building X instead of pouring concrete on wall footings during week Y). In our experience, this level of tracking may be a challenge as the control infrastructure (roles, reporting systems, and technology) usually is more general. The technology leader must work with the field operations manager to put a proper control infrastructure in place.

**Train modelers on product and process modeling:** Modelers must learn the specifics of product and process modeling related to the FIPAPM method (i.e., product and process information schemas, process modeling language, and coordination needs between product and process models). This training is particularly important for process modelers as formal process models are not common in the construction industry and they will need special skills (e.g., abstract the practical knowledge of

field personnel) to facilitate the discussions among the construction experts (see next step) and to create consistent and valuable process models. This type of skills is similar to the knowledge acquisition skills of knowledge engineers described in the artificial intelligence literature (Kidd, 1987; Diaper, 1989; Hart, 1992). The technology leader should consider the help of consultants to support the process modeling training and initial modeling of the company's best practices.

**Model the company's construction best practices:** This modeling happens in sessions to capture construction knowledge. The length of these session depends on how many construction processes will be reviewed and if it is an initial modeling or an update (see next step). In these sessions, the construction experts brainstorm and discuss the best practices for all the construction activities the company normally performs and the usual scenarios (technological, technical, managerial, etc.) that can affect those best practices. The process modeler must facilitate this discussion as it is hard for the construction experts to abstract their field knowledge. For example, foremen may discuss the many different construction solutions they use to protect a footing excavation and the process modeler has to ask the right questions to identify what those solutions depend on (e.g., water table elevation, soil bearing capacity, excavation depth, rain probability), the construction steps involved in each solution, and what equipment and tools are needed for each solution so the construction process can be abstracted from the specific conditions of a particular scenario. The process modeler also must translate this discussion into a process model (e.g., Figure 7 shows a simple process model). These process models can be used not only for producing field instructions but also for new personnel training and process reengineering.

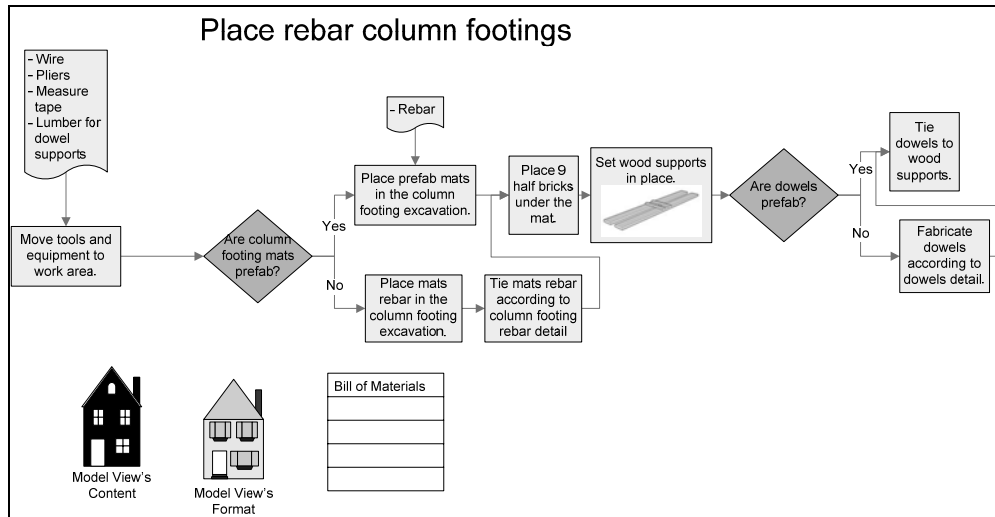


Figure 7. Process model for placing rebar of the column footings. Mourgues et al. (2008) explains the process information schema and process modeling language in detail.

**Update models of company’s construction best practices:** The construction knowledge embedded in the process models must always be up-to-date so the field instructions derived from it are correct and reliable. If field management or laborers find the instructions incorrect or unreliable they will not use the FIPAPM method. Therefore, the construction knowledge must be revised and updated during the knowledge capture sessions at least every 6 months or every time a new technology, regulation, or work procedure is introduced in the company.

**Create product modeling guideline:** The product modelers together with the process modeler must define the company’s product modeling guideline to ensure that the product models can be used in the FIPAPM method and it is consistent with the practices of the company in terms of both level of detail and content. The consistency of the level of detail means that the CAD elements in the model must represent the building components at the same granularity in which the laborers work with them (e.g., if a slab is poured in 2 sections, the slab’s CAD elements must represent exactly each of those sections and not the whole slab as a single CAD element). The content consistency means that the product model must be consistent with the references to building components in the process models (in the entities “model view content”,

“decisions from product model information”, and “bill of materials”). These references can include temporary components related with the company’s best practices to perform construction activities.

## **5.2. Implementation steps executed at the project level**

**Provide proper IT infrastructure for the project:** The technology leader must ensure that the projects have the infrastructure needed for the FIPAPM method: access to company’s product and process models, software for product and process modeling, software for producing field instructions, proper computer (i.e., ruggedized laptop that can explore 3D models of the size needed by the project), large-format color printer, and a proper work space. Also, the technology leader must continuously monitor these infrastructure needs (see below the step related to implementation metrics).

**Create project’s 3D model or adapt external 3D model of the project:** The product modeler must create the 3D model for the project either from scratch or using models that other stakeholders of the project have created (if they exist and are available).

**Produce field instructions using FIPAPM:** The field management must create field instructions on a daily basis to communicate the design and construction information that laborers need to perform their work. Depending on the size of the project and the field management setup (i.e., number, organization, and responsibilities of the professionals), it may be better to have each foreman produce field instructions for his/her own crews or to have the superintendent produce the instructions for the all the crews. The person who defines the activities of a crew or group of crews is the best person to also produce the field instructions for that crew or group of crews. The person producing the field instructions must be able to modify the content of the instruction – in any of the sections (drawings, instructions, equipment and tools, and bills of materials) – but s/he must also be accountable for the changes and must



communicate them to the product or process modelers (depending on the type of change) to assess if the changes need to be incorporated in any of the models.

**Use field instructions:** Laborers must use only the field instructions to do their work. They must not use the traditional drawings. If the instruction is missing information or contains outdated or incorrect information, laborers must inform the field management and technology leader.

**Track the work done:** Field management personnel must use the field instructions provided to the laborers to track the work that has been done. These field instructions provide, besides the work scope, details about the construction procedures – that may have been revised and thus differ from the information in the process models – and the design information – that may include more updated information than the construction drawings – used for that work scope.

**Keep project’s 3D model updated:** The product modeler must update the model daily based not only on official change orders that change future work but also based on “as is” information of work already done and unofficial change orders that are decided in the field. The ideal situation is to have a 3D modeler onsite who learns directly about the changes that affect the model. Otherwise, the 3D modeler in the main office must keep daily communication with the superintendent to learn what changes have been made in the field and with the project manager to learn about change orders.

**Gather and evaluate implementation metrics:** The technology leader must gather metrics about the use and impact of the FIPAPM method (refer to the “define implementation control method” step above). Additionally, the technology leader must track the field management’s infrastructure needs to support the FIPAPM method, training needs of the modelers and field management, results of incentives, and

workers' motivation. The evaluation of these metrics and needs must guide changes in the implementation process.

## 6. Conclusions

Implementing a method such as FIPAPM in a contractor's organization is a challenging endeavor especially in the individual and social domain of the culture of the construction industry. We presented a case study that explored the challenges during an implementation we led and analyzed them in the context of implementation challenges and strategies found in the relevant literature. As a result, we presented a guideline to help contractors to implement the FIPAPM method.

The implementation barriers we found during our case study include: technology maturity, poor IT infrastructure, data quality and reliability, low technology literacy, fear of change and uncertainty, knowledge abstraction, change of the work processes, need for role descriptions, technology leadership, high workload, top management support, tight project timeframes, and industry fragmentation. All of these barriers were already described by the relevant literature with the exception of knowledge abstraction that is a skill specific to the type of method we were implementing. This barrier has been studied by in the field of artificial intelligence about 20 years ago. Based on strategies that deal with the identified barriers, we defined the actors, their roles, and the steps of the implementation guideline. The presented study has the following limitations:

- **Focus on CIP concrete construction operations.** Mourgues et al. (2008) developed the FIPAPM method within the CIP concrete domain so we had to perform the implementation study in the same domain to isolate the implementation challenges from challenges that can be related to the applicability domain of the method. However, the presented implementation guideline should

be a good starting point for a more general implementation study for diverse types of construction operations once the FIPAPM method is extended to other disciplines.

- **Active participation of researchers in the implementation process.** This active participation may have hidden or diminished the effect of some challenges such as high workload and lack of technical skills. Future studies should try to reduce the researchers' participation in operational tasks (e.g., modeling and instructions production) and focus on observation of the implementation process and support of high level tasks (e.g., definition of strategic plan and implementation control method).
- **Short period of implementation.** The tight time frame of the study forced us to limit the preparation of the company's personnel involved in the implementation and to focus on the project level. We did not try to implement the FIPAPM method for the whole company. Future studies should last at least a couple of months including preparation and field work.

Considering these limitations, the presented guideline provides an initial framework for companies to define their implementation strategy. This guideline also enables researchers to perform a more detailed implementation study as they can track the use of this guideline by a contractor and provide insights that will help refine the implementation guideline.

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