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Construction projects tend to run over time and over budget, therefore a change in the industry is needed. Lean construction, with Just In Time and autonation, is the solution supported in the literature review. The following chapters define a built to order web-based software prototype with an e-tendering system and an automated inventory manager to reduce the cost of the construction materials and to handle the on site materials in a more efficient way. Just In Time material delivery principles are implemented and this dissertation should be seen as a first step towards a fully functional material management application.
Acknowledgements

I want to say “Muito obrigado!” to João Poças Martins, for his patience, influence and ability to translate my ideas into a feasible project and for his guidance throughout all the process.

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<td>Advanced Material Management Application</td>
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<td>BIM</td>
<td>Building Information Modeling</td>
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<td>CRUD</td>
<td>Create, Read, Update, Delete</td>
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<td>Just In Time</td>
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<td>Logical Data Model</td>
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<td>Less Than Truck Load</td>
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Chapter One: Introduction

1.1 Background

Material management, which includes procurement, order, inventory and consumption, requires special attention because controls great part of construction stage (Hendrickson, 1998). Moreover, it includes a huge variety of products because they go from materials unchanged since the beginning of the twentieth century when mechanization was introduced (e.g. bricks, plaster, tiles); to, high tech materials used these days by the top architects in their iconic buildings (e.g. aerogel, plaster with PCM). In either case, it is a usual fact that construction projects run over time and over budget (A.T.Kearney, 2012). This is no longer accepted by the industry and a change is needed.

In order to address this issue, new techniques must be adopted and, as it has happened to other sectors, construction has to modernize itself and promote the use of Information and Communication Technologies (ICT) to increase its productivity and efficiency thus reducing costs.

In this way a lot of progress have been made on the design stage with the implementation of BIM softwares, but the construction process is being left aside for the big software companies, and site managers have to rely on traditional methods such as paper based notations or spreadsheets to keep record of the on site material inventory and trust on their experience and the phone to purchase and order needed items. This is a repetitive operation that with the existing technology the site manager should be discharged from it thus being able to focus on the problems that arise during the construction phase.

This thesis pursues giving a feasible solution to the site managers on their daily activities, freeing them from inefficient work while increasing the presence of ICT on the construction site.
1.2 Aims and Objectives

The main aim of this dissertation is to develop software prototype for a more efficient material management on construction sites.

To achieve the aim of this research, the following objectives are established:

- Understand the foundations of a lean production system and investigate the Just In Time material delivery techniques.
- Justify the adoption of Just In Time material delivery with the achievements of previous researches.
- Take advantage of BIM potential and build a strong collaboration with BIM software thus reducing unnecessary steps between design and execution stages.
- Develop a system to reduce material costs using an e-tendering process integrated in the software environment.
- Create a built to order application with e-tendering and automatic Just In Time material delivery.
- Demonstrate the software performance with an use-case.
- Use as many free and open source development tools as possible.

1.3 Research Methodology

The methodology used in this dissertation can be broken down into three main parts. The first, an empirical literature review that enlightened the understanding of non-traditional construction processes as well as an in-depth analysis of the material delivery systems from other sectors that act as a justification for later chapters.

The second phase is a new learning in programming language that was needed to adapt the initial idea to a working software prototype.

The last stage takes the form of a case study where the previous concepts are tested and recommendations for an improvement are made.
1.4 Limitations and Scope

Being the background of the researcher construction engineering, it is beyond the scope of this dissertation to create a fully functional application ready to commercialize. Here a theoretical justification based on previous researches is given and a software prototype is presented.

The reader should bear in mind that this research is based on the lean construction principles, therefore the application relies on the Just In Time material delivery.

Due to privacy constraints of the manufacturers, this dissertation cannot provide RFID integration with the software even though this should be an essential element for tracking down the materials in the commercial version of the software.

1.5 Dissertation Report Outline

The overall structure of this dissertation takes the form of six themed chapters. The first one is the introduction thus deals with the motivations that led to undertake this research and give a general overview about the whole report. Chapter two is a critical review of the existing literature regarding lean construction and material management in the construction sector. It also establishes a strong and trusted backing point to justify the lean construction and the Just In Time material delivery. The third section introduces the software and gives a comprehensive view to its architecture and its main functionalities. The fourth chapter defines the database management system chosen to support the application and its structure is detailed. In Chapter five an example of the application functionalities is given, establishing an empirical evidence that the prototype can be used as a part of a more efficient management system. Finally, in the last chapter, the conclusion gives a critical summary of the findings as well as of the process followed to develop the prototype. A discussion of the findings implication to further research is commented, and to conclude, further research areas are identified.
Chapter Two: Literature Review

2.1 Introduction

According to a study from A.T. Kearney (2012) 63% of the projects are over budget and 57% of new construction projects fail meeting their timeline. One of the main reasons is due to a poor material management strategy, because a construction project schedule is controlled up to 80% for the material timely delivery (Ying, 2013) and material cost may represent up to 60% of the total budget of a typical construction project (Kini, 1999). Therefore an effective material management system is highly important to improve the productivity and to control the costs during the construction stage. The solution presented in this thesis to control budget and time relies on the basis of lean production system because “*lean can improve project time and cost performance and it may also have an impact on sustainability*” (Song and Liang, 2011).

Two main pillars are needed to support a lean system: Just In Time (JIT) and Autonomation (automation with human collaboration). But a zero error management system and a close relationship with the suppliers are vital elements as well (Ohno, 1988).

This thesis introduces a build-to-order material management system for the construction industry based on JIT material supply with an e-tendering process.

2.2 Just In Time

JIT can be defined as a form of logistics by consumption where a minimum level is near to zero and the order size for the element is close to one (Bertelsen, 1997). In other words, almost all that comes in is consumed.

When buying material it is a common practice that if the quantity to be purchased is greater than a specific price-break number, the supplier offers size discounts to encourage customers to place larger orders (Cha and Moon, 2005).

There are two types of discount to be considered:

- All-units discount: all units have a discounted price when the purchased quantity exceeds the price-break amount.
- Incremental discount plan: the discounted price applies only to the units over the price-break quantity.
Although large orders may be granted with discounts on the final price, this practice goes against the main JIT principle because more material than needed is being bought and a place at the construction site has to be set up for its temporary storage. This temporary storage area is not usually a place specifically designed for that purpose, and, in general, is messy and in disrepair, which can lead to damage from weather conditions and from the movement of equipment and people (Agapiou et al., 1998). On the other hand, the vendor usually has a designated place for holding inventory only, therefore its holding cost per unit per time are lower than the buyer ones. Consequently, placing an order while the buyer has some inventory left is never optimal, economically speaking (Ertogral et al., 2007). It is important to highlight that in the traditional construction industry most of the materials are purchased and delivered under an ad hoc basis (Clausen, 1995). This doesn’t look at the project big picture and can trigger interruptions to the working schedule due to delays and have materials on site not needed for days. With this in mind, it is important to stress that a JIT structure the material procurement system has to be very efficient and effective so there will not be lack of materials, lateness or work interruptions that would delay the whole project, because the timeline of the project is more dependent on the material delivery that it is with the traditional system.

Analyzing the transportation costs, Baumol and Vinod (1970) were the first to take into account the freight costs as an independent cost, however Ben-Daya et al. (2005) did an extensive review of how most of the existing literature assumed that “transportation cost is part of the ordering cost.” It was not until the deregulation of the transportation sector in the United States that transportation cost was separated from the ordering cost (Ertogral et al., 2007). Vroblefski et al. (2000) stated that “transportation costs tend to be mostly volume-dependent” and Ertogral et al. (2007) likewise disassembled the earlier idea because transportation cost is affected, among other factors, by shipment size and routing decisions. Henceforth can be stated that material cost and transportation cost are two separate concepts that do not have to belong together.

Going deeper into the transportation costs, can be stated that “most conventional carriers offer quantity discounts on the unit rate charged, depending on the volume shipped” (Vroblefski et al., 2000). Even though some transportation rates may be difficult to understand, the most common practice used among carriers is to differentiate between full truck load (TL) and less than truck load (LTL) shipments. Economically speaking, when the shipment is on TL conditions the transportation, on a cost per unit basis, is lower than if it was on LTL (Vroblefski
Over the years the coordination between supply or vendor and demand or buyer has centered the researchers attention (see Goyal and Gupta (1989) and Thomas and Griffin (1996) for a comprehensive review). An interesting approach is the one made by Banerjee (2009) where a set of products which individually were uneconomical to move with TL shipments were joined together on the same truck until a final TL was obtained. This combination integrated with a periodic TL shipping schedule resulted in a more “streamlined supply chain” (Banerjee, 2009) and “the supply chain as a whole becomes more coherent from an operational perspective” (Banerjee, 2009). With this intention, a close relationship between the vendor and the buyer is needed. As a result, the supplier will have higher control of the inventory because the system works synchronized with the buyer and orders can be foreseen, and at the same time, the buyer can have low inventory levels. This approach is very interesting for JIT production where the demand rate of a single product may not be enough to assure periodic individual TL shipments, but on the other hand, if a group of low-demand goods are shipped from a single location a feasible option is to group them in order to completely fill a truck with its consequent full truck load shipment rate.

When the transport is not from a single location, but a local suppliers network is used, it is possible to group several LTL to get a TL using the milk run system (Brar and Saini, 2011). This system can be applied whenever there is more than one supplier, more than one construction site to deliver the material to, or both, because the principle is the same, only logistic changes will be needed to get efficient loading and unloading operations.

Milk run system is a method of collecting goods used on JIT activities (see Figure 1) where the buyer sends one truck every specific time to visit various suppliers following a predefined route to collect different items and deliver them to the construction site (Sadjagi et al., 2008).

![Figure 1: Difference between traditional transportation and milk run system (Brar and Saini, 2011).](image-url)
According to Brar and Saini (2011) milk run system has multiple benefits: cuts down the fuel consumption and therefore the CO₂ emissions by reducing the truck deliveries; the travelling path decreases; transportation cost diminishes and also the number of trucks on the road drops. This system uses the trucks in a more efficient way and the average loading factor becomes higher.

Despite the theory shown above, to determine if the system is efficient, each project has to be analyzed independently from the logistics and construction perspective and; the construction volume, the distance to suppliers and between them, the delivery schedule and the transportation route have to be evaluated because these are factors that affect the shipment size and cost. This is what Song and Liang (2011) mean by “a reformulation of the practices and processes of the construction industry” to have the whole construction operational structure in mind and analyze how the external stakeholders interact with the project and find the best possible combination. To do so in a coordinated way, the Sophiehaven housing project in Denmark chose, as organizational form, the partnering between all project participants (Agapiou et al., 1998). With partnering teamwork is essential and it requires openness between the parties, acceptance of new ideas, trust and looks for the continuous improvement (Latham, 1994) and it is probably the only way to see the project globally.

The Sophiehaven project was the first to introduce JIT principles for the material delivery, and a saving of the 9% of the total net building cost was obtained (Bertelsen, 1993).

Bertelsen (1993) documented the Sophiehaven project and he stated that on the logistics field there are two different principles:

- Logistics by planning: the material is required according to the foreseen planned consumption.
- Logistics by consumption: the material is required when a minimum level is reached.

The combination of this two principles seems to be desired; “a planning approach on the overall level and a consumption approach in the day-to-day operation” (Bertelsen, 1997) in other words, a global planning where the general parts to be built are defined, and a day-to-day planning undertaken from the construction site where the specific elements are defined to be built in a day-ahead basis.

Accordingly to the above, on the Sophiehaven project besides the daily management operations, weekly meetings were kept to check the progress of the global planning and the daily tasks for the next 3 weeks were established.
or modified if necessary. The daily tasks were conceived as “units” where each one was packed into a ready-to-use package with all the material needed to its completion and the equipment necessary for its installation was detailed. The package also had an identification number specifying the supplier, the content, and the subcontractor to receive the material (see Bertelsen (1993), Bertelsen (1997), and Agapiou et al. (1998) for an extensive review of the project).

The main object of JIT is “to minimize waste of materials, time and effort in order to generate the maximum possible amount of value” (Koskela et al., 2002). Value does not need to be only economic, because on the Sophiehaven project, apart from the 9% of savings of the net building cost, the workers perceived a higher degree of safety and the moral of contractors, foremen and workers was noticed better too (Bertelsen, 1997), accordingly, JIT can also create a better working environment.

Construction sites are unforeseeable because they rely on variable events (Thomas et al., 2002). Those include workforce performance, weather conditions and delivery times of third parties among others. Therefore, real-time data is needed to undertake effective and efficient planning decisions (Sardroud, 2012). As discussed next, the use of Radio Frequency Identifiers (RFID) would be a perfect solution for collecting real-time data.

2.3 Autonomation

The construction sector is characterized by “the procurement of high levels of unstructured goods and services” (Grilo and Jardim-Goncalves, 2011) thus, the use of electronic procurement systems are difficult to implement (Grilo and Jardim-Goncalves, 2011). This is because the traditional e-commerce system supplies standardized products from the factory to the client, whereas in the construction industry it is usual to have specially designed products for each project, for example the steel columns cannot be standardized in length because its length is project-dependent. Moreover, the information necessary or specifications for the contractual agreement for the same good normally varies from one project to another. Under these premises this thesis defends a combination between e-tendering and e-commerce system where the suppliers will be invited to tender for each material knowing beforehand its particular specifications and delivery conditions.
Samuelson (2003) showed that the use of Information and Communication Technology (ICT) is highly implemented in the construction industry for design and facility management operations. On the other hand, contractors and site workers in the construction phase rarely use it. One of the reasons why this happens might be because the software companies have been focused only on the design stage, leaving the production relying on handmade notations or to software not specially designed for construction like ERP or even spreadsheets.

An interesting technology everyday more present in the design stage and that can be essential for the introduction of lean construction is the Building Information Modeling (BIM). The use of BIM has skyrocketed a 45% from 2009 to 2012 in the United States, and today more than 70% of contractors, engineers and architects are BIM users (McGraw-Hill, 2012). When a company is working with BIM it is easier to directly obtain quantities from a model, but the organization of the tendering elements is a complex issue (Grilo and Jardim-Goncalves, 2011).

BIM software is also interesting because it usually offers the possibility to represent the designed model in 3D. Therefore, BIM software can be the boosting tool needed to implement lean in the construction industry, because, as stated by Song and Liang (2011), 3D visualization models help to implement lean at the operational level.

Enshassi (1996) concluded that an early and accurate scheduling of the materials, planned to a time schedule and linked to the master plan is highly desirable. At that time though, this was impossible to do because the initial details had limited value, either because they were incomplete, or variations were made before the construction had even started (Bishop, 1966). Nowadays, with the available BIM software where Bill-of-Quantities are available with just few clicks, details can be added to the drawings and clashes are seen before variations have to be made, it is recommended to schedule the materials at an early stage of the project.

With all this in mind, this thesis presents a software where information is extracted from the BIM model and introduced into a database with special codification to allow an e-tendering process aiming to obtain cheaper materials. Moreover, and following the ideas of Enshassi, the bidders will be able to have the detailed drawings and specification of the materials ahead of time hence make more accurate bids and its general delivery time will be scheduled at an early stage of the project and linked to the master plan with the JIT outlook in mind.
Another need that appears when introducing automation in the construction process is the need of real-time data to undertake effective and efficient planning decisions. As recent studies have demonstrated (Ren et al., 2011, Sardroud, 2012 &, Lee et al., 2013), for the automation of construction resources RFID technology is the best way to obtain accurate and real-time information throughout resources lifecycle and automatically incorporate it into the information management system almost without any human intervention. RFID are better than other technologies such as barcodes for the construction industry because RFID can track resources in real-time without line-of-sight or contact and the tags can withstand rugged and harsh environments (Schneider, 2003). Moreover, the read rate of the RFID-tags is 99.9% whereas for the bar codes is 80% (Schneider, 2003).

RFID has also proved its utility when used as a part of a quality management system. Reisbacka et al. (2008) embedded RFID-tags on concrete structures enabling them to be identified using mobile phones on the construction site. If this technology can be used in all the construction elements, RFID will be the most suitable technology to implement the zero error policy because it may be used to assure that no element has poorer quality than the specified and the extracted data can then be incorporated into the information management system.

To assure the zero error policy the elements should not only have RFID-tags, but also a human readable code just in case there is a malfunction of the RFID tag/reader or any other unforeseen problem.

To standardize the codification of each construction element, the North American architectural, engineering and construction industry created the OmniClass Construction Classification System. It provides a “classification structure for electronic databases” (OmniClass, 2006) and fulfills with the ISO 12006-2 (International Organization for Standardization, 2001). This codification system is really useful for relating the designed elements in BIM to the buildable elements on the application. In particular “Table 23 – Products” (OmniClass, 2006) suits perfectly for this purpose and is used as a relating ID in the application.

Accordingly to all the above, the following chapters introduce the main aspects of the software prototype and defines its key operations.
Chapter Three: Software Architecture

3.1 Introduction

This chapter gives a comprehensive architectural overview of the Advanced Material Management Application (AMMA). It presents the aspects of the system to illustrate its multiple architectural views. This chapter is envisioned to capture and transmit the major architectural components that the system has.

3.2 Application functions

A list of the software key functions is defined here. The software has to:

- Store a suppliers database.
- Import elements from BIM software.
- Invite suppliers to bid for materials and store the bids for its acceptance by the user.
- Maintain inventory levels and automatically purchase those items requested based on a minimum stored quantity.

Figure 2: AMMA application conceptual model.
3.3 Software Overview

The AMMA is designed to perform a more efficient material management on the construction sites. The operations to be executed are drawn in Figure 2 to get an overall idea of the application functions, but an extensive in depth description can be found in this chapter and the following one.

3.4 User Characteristics

The user is expected to be the site manager of a construction project; therefore Internet connection and basic knowledge of personal computer usage are needed. The construction knowledge is assumed *per se*.

3.5 Views

In this point a detailed description of the views defined by the “4+1” model are given. The structure chosen to represent the software as precisely as possible, is based on the “4+1” model view of architecture (see Figure 3). To adapt the visual models to the standards, the views are modeled using the Unified Modeling Language (UML) because as defined by Rumbaugh et al., (1998) UML is a visual modeling language used to visualize and document the artifacts of a software system. This method is able to capture the decisions and understandings about systems that are being developed.

![Figure 3: The “4+1” model with its views and stakeholders (Kruchten, 1995).](image-url)
3.5.1 Logical View

The Advanced Material Management Application is divided into layers based on the three-tier architecture (see Figure 4).

![Diagram of three-tier architecture](image)

**Presentation tier**
- The top-most level of the application is the user interface. The main function of the interface is to translate tasks and results to something the user can understand.

**Logic tier**
- This layer coordinates the application processes commands, makes logical decisions and evaluations, and performs calculations. It also moves and processes data between the two surrounding layers.

**Data tier**
- Here information is stored and retrieved from a database or file system. The information is then passed back to the logic tier for processing, and then eventually back to the user.

Figure 4: Three-tiers architecture visual representation (SUNSOFT, 2013).

The tiers or layers of the application are based on a responsibility approach that links each layer with a specific mission. Using this strategy the system responsibilities are isolated and this improves maintenance and system development (Eckerson, 1995).

As described below, each tier has specific responsibilities:

- The presentation layer deals with the appearance of the application as well as the visualization of the data by the user. HTML and Cascade Style Sheet (CSS) are used in this layer of the application.

- The logic layer is the middleman between the user and the database where the data is kept. In this tier the control rules are written so they work as per the needs of the application. The code used in this tier is PHP embedded into HTML source code.

- The data layer is the part where the rules for the database access are written and performed. The language used in this layer is SQL and perform the operations of create, read, update and delete into the MySQL database. These SQL statements are embedded in the PHP code.
3.5.2 Process View

In this section the system is decomposed into single threads of control or lightweight processes and heavyweight processes. A description of the three principal modes of communication between processes is given next.

3.5.2.1 Start Bidding Process

The user triggers the bidding process when all the elements are already imported from the BIM software and he wants to start receiving bids for the materials.

Initiating the process (see Figure 5), the logic tier queries the database for the suppliers ID and the e-mail that match with the OmniClass code of the material. The data tier finds those suppliers and then sends the list back to the logical tier where the invitations to bid are sent to the suppliers via e-mail.

3.5.2.2 Place a Bid

When the user starts the bidding process, the supplier ends up receiving an e-mail with an invitation to bid. This e-mail contains a link that directs the supplier to a web form that has to be filled in and submitted to formalize the bid.

Once the form is submitted, the logic tier processes it checking that all the fields fulfill the conditions (see Figure 6). Once the form is checked the logic layer sends the form information to the data tier where a new row is created into the “bidding” table.
3.5.2.3 Daily Update

The application is able to automatically update the quantity of material available on-site performing basic mathematical operations. To do so, a script has been programmed to run once a day. This script will subtract from the “onsite” table the quantity utilized that day by the workers (the workers performance can be adjusted by the user by adapting the “worker_perf” table). This daily update can be done because a logistics by consumption of materials is considered in this stage of the project.

The script is run by the logic tier and sends to the data layer a request to know all OmniClass IDs from the “onsite” table (see Figure 7). Once the IDs are received these IDs are then requested to the “worker_perf” table and the quantities to subtract from “onsite” are sent back. After the logic layer has performed the operation, the new quantity is updated into the “onsite” table.

![Daily Update Process Diagram](image)

Figure 7: “Daily Update” process diagram.

3.5.3 Development View

This view is also known as the implementation view and it describes the whole structure of the implementation model, the software is broken down into subsystems and layers in the implementation model and any significant component of its architecture should be shown.

In this case the layers of the development view match the ones defined in the logical view (see paragraph 3.5.1 Logical View), therefore it is unnecessary to document this view in further detail.
3.5.4 Physical View

The Physical View is also known as Deployment View and it shows the hardware configuration or physical network on which the software runs (see Figure 8). On it the data organization can be seen and it is easy to understand how the user can get the information stored into the database.

The user through the web browser accesses the application server and the web server (Apache in this case) is the responsible for querying the database and getting the requested data thanks to the logic tier. Once this data is read, it is pulled back to the user web browser.

![Figure 8: Hardware configuration for the application.]

3.5.5 Use-Case View

This section shows scenarios from the use-case model with more importance on the final system. For the Advanced Material Management Application there are four use-cases with major impact on the main functionality of the final system. The first one is the suppliers registration; the second one is the import of elements, then the bidding with the material order placement is presented, and the last one is the daily update script.

To introduce each use-case a flow diagram presents the case for its main actor and a sequence diagram is used to define the stages of the case. These cases are better developed in chapter five where a real example is shown.
3.5.5.1 Suppliers Registration

A new supplier wants to register on the application to start receiving offers to bid. On the website main page the supplier has to fill in the form with his personal information and select the supplied products family. Once done, the database will be updated and he will start receiving offers to bid (see Figure 9).

Detailed description:

- **Use Case:** Suppliers Registration
- **Identifier:** UC1
- **Description:** Supplier wants to sign up in the application
- **Actor:** Supplier
- **Preconditions:**
  - Supplier is connected to the web page
- **Flow of events:**
  - The Supplier fills in the form and submits it.
  - The form is processed and if everything is correct the supplier is added to the database.
- **Postconditions:**
  - Successful registration message is displayed

![Figure 9: “Suppliers Registration” flow diagram.](image)

![Figure 10: “Suppliers Registration” sequence diagram.](image)
3.5.5.2 Import Elements

Once the design phase is over, the model is ready to be imported to the application. To do so, the user has to export the model from the BIM software into the MySQL database using an Open Database Connection (ODBC) protocol with the BIM software capabilities to do so (See Figure 11). No sequence diagram is shown in this section because the importation is performed from the BIM software (See section 5.4 Export from BIM for an in depth example).

```
- Use Case: Import Elements
- Identifier: UC2
- Description: Users import the list of elements from the BIM software.
- Actor: User
- Preconditions:
  - User is registered on the system.
  - User has a model in a BIM software.
- Flow of events:
  - User logs in into the application.
  - User starts the BIM software.
  - User exports the model using ODBC into the selected database.
- Postconditions:
  - Web master checks that the import has been successful.
```

3.5.5.3 Bidding

```
- Use Case: Bidding
- Identifier: UC3
- Description: Users can start the bidding process.
- Actor: User
- Preconditions: 
  - User has a model in a BIM software.
- Flow of events:
  - User clicks on the "Start Tender" button.
  - E-mail sent to supplier.
  - Supplier responds with a bid.
  - Supplier accepts the bid.
  - Order for material is placed.
- Postconditions:
  - Supplier has received the email.
  - Supplier has accepted the bid.
  - Material is ordered.
```
When the user is logged in into the application and the materials are imported from the BIM software, the bidding for materials can start. With this process, the suppliers will receive an e-mail with the material information as well as the delivery conditions. The supplier will make a bid and if it is accepted will receive an e-mail confirming the order. See Figure 13 and 14 for a visual representation.

Detailed description:

- Use Case: Bidding
- Identifier: UC3
- Description: Users wants to start the bidding process.
- Actors: User & Supplier
- Preconditions:
  - User is logged in into the system.
  - User has imported the elements from BIM software.
  - Supplier is registered on the system.
- Flow of events:
  - User logs in into the application.
  - User starts the bidding process.
  - Suppliers receive an invitation to bid and answer it or not.
  - User accepts the bids and by doing so the order is placed.
  - Supplier sends the material to the site.
- Postconditions:
  - Material arrives on site.

Figure 13: “Bidding” sequence diagram.
When the bidding process is closed, the user has to accept the best bids. Figure 14 describes this case with a sequence diagram.

3.5.5.4 Daily Update

Having material on site implies that it is consumed according to a worker’s performance. At the user’s will a daily script runs to check what is the quantity of material stored on site. If the quantity is smaller than the minimum stored quantity defined by the user a new order will be placed, if it is not, the new quantity will only be updated into the database. A sequence diagram representing this case can be seen on Figure 15.

Detailed description:

- Use Case: Daily Update
- Identifier: UC4
- Description: The quantity of material stored on site decreases according to the worker’s performance.
- Actor: Application
- Preconditions:
  - Have some material stored on site.
- Flow of events:
  - Daily update process is automatically triggered.
  - Quantity of material on site is obtained.
  - Logical layer carries out reduction of the quantity according to the worker’s performance.
  - New quantity of material on site is updated.
  - If the new quantity is smaller than the minimum stored quantity a new order is placed.
• Postconditions:
  o If a new order has been placed, the postcondition is that the material will arrive on site.

Figure 15: “Daily Update” sequence diagram.
Chapter Four: Database Design

4.1 Introduction

Data modeling is an activity used during the software development process of information systems when data is stored into a database. The output is a graphical representation of the data model describing the information structure regarding entities and their relationship, what is called an Entity-Relationship Diagram (ERD). The main purposes of the data model for a system are:

- Specify conceptual description of the objects and their relationship.
- Define a blueprint for the creation of the database structure.
- Facilitate stakeholder’s communication in application analysis.

4.2 Database Overview

The AMMA database provides the physical storage structure and schema for the tables supporting the application. The database is constituted of two different types of tables. The first type supports AMMA with all the suppliers and users; the second one is the project itself and therefore is user dependent.

The AMMA database handles the storage, retrieval, and updating of the modeling database. The AMMA database is connected by the application using PHP code as defined in the section 3.5.1. Logical View. In this chapter all components of the AMMA database are defined.

4.3 Database Management System

A database is only a structured collection of data, but in order to create, read, update, delete and administrate the database a database management system (DBMS) is needed.

A wide variety of DBMS are available in the market today (MySQL, PostgreSQL, SQLite, Microsoft SQL Server are the most popular). Among all of them the DBMS chosen for this application is MySQL. The reasons that led to this election are the following ones (DuBois, 2005):

- Cost: it is an open source project and available for free under the terms of General Public License.
- Speed: MySQL developers claim that it is the fastest database system on the market.
• Ease of use: although being a high-performance system it is relatively simple to set up and administrate.
• Query language: MySQL understands Structured Query Language (SQL).
• Connectivity: it can be accessed from anywhere on the Internet.
• Capability: MySQL is multi-thread, which means that many clients can access to it simultaneously using multiple databases at the same time. MySQL can be accessed with PHP and using applications that support ODBC.

4.4 Detailed Database Design

To make understandable the structure of the data entities (tables) and their relationship a detailed description of the DBMS associated with the application is given here. To do so the Logical Data Model (LDM) is used.

The LDM is usually the subject of normalization because it stays between the Conceptual Model which is an abstract design and the Physical Data Model more concerned with the implementation and which incorporates optimizations (see Merson (2009) for an extensive review).

4.4.1 Tables

A listing of the tables with its columns is given here. A brief description of each of these columns is also included in the Table 1. The tables from the ODBC importation of the model are not included on the list because are generated automatically and are very large, instead a table representing all of them is presented in the table under the name of “elements”. However all the tables represented by “elements” can be found at Appendix 2.

<table>
<thead>
<tr>
<th>Table</th>
<th>Column Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>accepted_bids</td>
<td>tender_id</td>
<td>Bid identification number</td>
</tr>
<tr>
<td>accepted_bids</td>
<td>supplier_id</td>
<td>Supplier identification number</td>
</tr>
<tr>
<td>accepted_bids</td>
<td>material_name</td>
<td>Material to be purchased</td>
</tr>
<tr>
<td>accepted_bids</td>
<td>material_id</td>
<td>Material OmniClass number</td>
</tr>
<tr>
<td>accepted_bids</td>
<td>host_element_id</td>
<td>Host element of the material</td>
</tr>
<tr>
<td>accepted_bids</td>
<td>technical_description</td>
<td>Material technical aspects</td>
</tr>
<tr>
<td>accepted_bids</td>
<td>accepted_price</td>
<td>Purchasing price</td>
</tr>
<tr>
<td>accepted_bids</td>
<td>accepted_date</td>
<td>Day bid was accepted</td>
</tr>
<tr>
<td>accepted_bids</td>
<td>onsite_arrival</td>
<td>Day order arrive on site</td>
</tr>
<tr>
<td>bidding</td>
<td>tender_id</td>
<td>Bid identification number</td>
</tr>
<tr>
<td>bidding</td>
<td>supplier_id</td>
<td>Supplier identification number</td>
</tr>
<tr>
<td>bidding</td>
<td>material_name</td>
<td>Material to be purchased</td>
</tr>
<tr>
<td>bidding</td>
<td>material_id</td>
<td>Material OmniClass number</td>
</tr>
<tr>
<td>bidding</td>
<td>host_element_id</td>
<td>Host element of the material</td>
</tr>
<tr>
<td>bidding</td>
<td>technical_description</td>
<td>Material technical aspects</td>
</tr>
<tr>
<td>bidding</td>
<td>price</td>
<td>Bidding price</td>
</tr>
<tr>
<td>bidding</td>
<td>open_date</td>
<td>Bidding process open date</td>
</tr>
<tr>
<td>bidding</td>
<td>close_date</td>
<td>Bidding process final date</td>
</tr>
<tr>
<td>bidding</td>
<td>conditions</td>
<td>Delivery or purchase conditions</td>
</tr>
<tr>
<td>omniclass23</td>
<td>omniclass_id</td>
<td>OmniClass identification number</td>
</tr>
<tr>
<td>omniclass23</td>
<td>omniclass_code</td>
<td>OmniClass code</td>
</tr>
<tr>
<td>omniclass23</td>
<td>title1</td>
<td>OmniClass Title 1</td>
</tr>
<tr>
<td>omniclass23</td>
<td>title2</td>
<td>OmniClass Title 2</td>
</tr>
<tr>
<td>omniclass23</td>
<td>title3</td>
<td>OmniClass Title 3</td>
</tr>
<tr>
<td>omniclass23</td>
<td>title4</td>
<td>OmniClass Title 4</td>
</tr>
<tr>
<td>omniclass23</td>
<td>description</td>
<td>OmniClass code specification</td>
</tr>
<tr>
<td>suppliers</td>
<td>supplier_id</td>
<td>Supplier identification number</td>
</tr>
<tr>
<td>suppliers</td>
<td>company_name</td>
<td>Name of the company</td>
</tr>
<tr>
<td>suppliers</td>
<td>company_username</td>
<td>Supplier username</td>
</tr>
<tr>
<td>suppliers</td>
<td>company_hashed_password</td>
<td>Supplier encrypted password</td>
</tr>
<tr>
<td>suppliers</td>
<td>company_mail</td>
<td>Supplier email to send invitations to bid</td>
</tr>
<tr>
<td>suppliers</td>
<td>company_phone</td>
<td>Supplier contact phone</td>
</tr>
<tr>
<td>suppliers</td>
<td>company_iban</td>
<td>Supplier IBAN number for payments</td>
</tr>
</tbody>
</table>

Table 1: List of columns and tables (1/2).
4.4.2 Entity-Relationship Diagram: Logical Data Model

On the Figure 16 a logical view of the DBMS can be seen. For this representation, the UML language is not used, instead the crow’s foot ERD notation is. The UML was not created for data modeling but for object-oriented modeling (Merson, 2009) and for this purpose the crow’s foot ERD notation was created by Richard Barker in the late 1980s (Barker, 1990). It is the most popular and suitable notation to be used on an ERD.

<table>
<thead>
<tr>
<th>Table</th>
<th>Column Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>suppliers</td>
<td>material_id</td>
<td>Material supplied (OmnClass code)</td>
</tr>
<tr>
<td>suppliers</td>
<td>material_name</td>
<td>Material supplied (OmnClass title 3)</td>
</tr>
<tr>
<td>users</td>
<td>user_id</td>
<td>User identification number</td>
</tr>
<tr>
<td>users</td>
<td>username</td>
<td>Username</td>
</tr>
<tr>
<td>users</td>
<td>hashed_password</td>
<td>User encrypted password</td>
</tr>
<tr>
<td>onsite</td>
<td>onsite_id</td>
<td>On site material identification number</td>
</tr>
<tr>
<td>onsite</td>
<td>material_name</td>
<td>Material name</td>
</tr>
<tr>
<td>onsite</td>
<td>material_id</td>
<td>Material supplied (OmnClass code)</td>
</tr>
<tr>
<td>onsite</td>
<td>host_element_id</td>
<td>Host element of the material</td>
</tr>
<tr>
<td>onsite</td>
<td>quantity</td>
<td>Quantity stored on site</td>
</tr>
<tr>
<td>onsite</td>
<td>surface</td>
<td>Surface occupied by the material</td>
</tr>
<tr>
<td>onsite</td>
<td>volume</td>
<td>Volume occupied by the material</td>
</tr>
<tr>
<td>onsite</td>
<td>supplier_id</td>
<td>Supplier identification number</td>
</tr>
<tr>
<td>onsite</td>
<td>arrival_date</td>
<td>Day order arrive on site</td>
</tr>
<tr>
<td>onsite</td>
<td>min_stored_q</td>
<td>Minimum stored quantity wanted on site</td>
</tr>
<tr>
<td>onsite</td>
<td>order_size</td>
<td>Size of the automatic order</td>
</tr>
<tr>
<td>worker_perf</td>
<td>worker_perf_id</td>
<td>WP identification number</td>
</tr>
<tr>
<td>worker_perf</td>
<td>material_id</td>
<td>Material to apply the performance</td>
</tr>
<tr>
<td>worker_perf</td>
<td>performance</td>
<td>Consumption of material per day</td>
</tr>
<tr>
<td>worker_perf</td>
<td>units</td>
<td>Units of the consumption</td>
</tr>
<tr>
<td>mat_usage</td>
<td>mat_usage_id</td>
<td>Material usage identification number</td>
</tr>
<tr>
<td>mat_usage</td>
<td>material_id</td>
<td>Material to apply the rate</td>
</tr>
<tr>
<td>mat_usage</td>
<td>rate</td>
<td>Rate of use of material</td>
</tr>
<tr>
<td>mat_usage</td>
<td>units</td>
<td>Units of the rate</td>
</tr>
<tr>
<td>elements</td>
<td>element_id</td>
<td>Element identification number</td>
</tr>
<tr>
<td>elements</td>
<td>host_element_id</td>
<td>Host element of the material</td>
</tr>
<tr>
<td>elements</td>
<td>phase_created</td>
<td>Phase when the element is built</td>
</tr>
<tr>
<td>elements</td>
<td>level</td>
<td>Level where the element is referenced</td>
</tr>
<tr>
<td>elements</td>
<td>measures</td>
<td>Total quantity of the element</td>
</tr>
<tr>
<td>elements</td>
<td>material_name</td>
<td>Material name</td>
</tr>
<tr>
<td>elements</td>
<td>material_id</td>
<td>Material OmniClass number</td>
</tr>
<tr>
<td>elements</td>
<td>min_stored_q</td>
<td>Minimum stored quantity wanted on site</td>
</tr>
<tr>
<td>elements</td>
<td>technical_description</td>
<td>Material technical aspects</td>
</tr>
<tr>
<td>orders</td>
<td>order_id</td>
<td>Order identification number</td>
</tr>
<tr>
<td>orders</td>
<td>host_element_id</td>
<td>Host element of the material</td>
</tr>
<tr>
<td>orders</td>
<td>supplier_id</td>
<td>Supplier identification number</td>
</tr>
<tr>
<td>orders</td>
<td>material_id</td>
<td>Material supplied (OmnClass code)</td>
</tr>
<tr>
<td>orders</td>
<td>material_name</td>
<td>Material name</td>
</tr>
<tr>
<td>orders</td>
<td>unitary_price</td>
<td>Material price per unit</td>
</tr>
<tr>
<td>orders</td>
<td>total_quantity</td>
<td>Total quantity of the element</td>
</tr>
<tr>
<td>orders</td>
<td>total_price</td>
<td>Total price</td>
</tr>
<tr>
<td>orders</td>
<td>number_of_packages</td>
<td>Number of packages out of the total</td>
</tr>
<tr>
<td>orders</td>
<td>order_size</td>
<td>Quantity ordered</td>
</tr>
<tr>
<td>orders</td>
<td>supplier_accepted</td>
<td>Day order accepted by supplier</td>
</tr>
</tbody>
</table>

Table 1: List of columns and tables (2/2).
4.4.3 CRUD Matrix

CRUD or Create, Read, Update and Delete are the four SQL equivalent statements:

- Create = INSERT new data into the DB.
- Read = SELECT data from an existing DB.
- Update = UPDATE data from an existing DB.
- Delete = DELETE data from an existing DB.

Therefore the CRUD matrix (see Table 2) defines the interactions between processes and entities of a system, allowing a clear representation on what process can modify each entity.
<table>
<thead>
<tr>
<th>Processes</th>
<th>accepted_bids</th>
<th>bidding</th>
<th>omniclass23</th>
<th>suppliers</th>
<th>users</th>
<th>onsite</th>
<th>worker_perf</th>
<th>elements</th>
<th>orders</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Registration</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>C</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Supplier Registration</td>
<td>-</td>
<td>-</td>
<td>R</td>
<td>C</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Import Elements</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R</td>
<td>-</td>
<td>C</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Invitation to Bid</td>
<td>-</td>
<td>C</td>
<td>R</td>
<td>R</td>
<td>-</td>
<td>-</td>
<td>R</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Suppliers Bid</td>
<td>-</td>
<td>RU</td>
<td>-</td>
<td>R</td>
<td>-</td>
<td>-</td>
<td>R</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Accept Bid</td>
<td>CRU</td>
<td>R</td>
<td>-</td>
<td>R</td>
<td>R</td>
<td>-</td>
<td>-</td>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>Order Material</td>
<td>R</td>
<td>-</td>
<td>-</td>
<td>R</td>
<td>R</td>
<td>C</td>
<td>-</td>
<td>CRU</td>
<td>-</td>
</tr>
<tr>
<td>Material Consumption</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R</td>
<td>CRU</td>
<td>CRU</td>
<td>-</td>
<td>CRU</td>
<td>-</td>
</tr>
<tr>
<td>Daily Update</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R</td>
<td>CRU</td>
<td>CRU</td>
<td>-</td>
<td>CRU</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2: CRUD Matrix.
Chapter Five: Case Study

5.1 Introduction

In this section an example of the application functionality is made to give a real example of how the application works and to demonstrate its capabilities. To carry out this demonstration the BIM software selected has been Autodesk Revit Architecture 2012 (Revit from now on), however, Archicad could have been used as well, because as stated on their website (Graphisoft, 2013) using Archicad ODBC Driver the Archicad projects files can be exported to a database.

The model used for this example is the basic sample project that comes with Revit. It is a project of a two storey detached house with bearing walls structure, wooden floor and metallic roof.

5.2 Supplier Sign Up

In order to foster the use of the application it should be free for the suppliers, therefore its registration have to be really easy. Following the example of social networks the main page of the prototype has two different parts: the sign in area for the users and the sign up zone for the suppliers (see Figure 17). When suppliers want to register they only have to fill in the form in the page and, if everything is correct, a confirmation message will appear (see Figure 18). The company legal identification number must be an essential requirement for the final version to check the truthfulness of the information given.

5.3 User Sign In

When the user is already registered in the application, and wants to start using it, he has to connect to the application’s main page, fill in the username and password (see Figure 17) and click the Login button.

Figure 17: Application main page
Figure 18: Successfully supplier registration.
5.4 Export from BIM

Once the design face is finished, the model from the BIM software has to be exported to the application database. It is important to mention that this exportation creates a table for all the elements defined in BIM, therefore all the layers of an element must be present on the BIM model.

This activity is necessary in all projects to start using the program. A detailed step by step example is given next.

A) Open the BIM model with Autodesk Revit Architecture 2012.
B) Go to File > Export > ODBC Database (see Figure 19).
C) Choose “Machine Data Source” and select a connection, “master_thesis” in this example (see Figure 20). The steps to configure a connection are given in Appendix 1.
D) Enter the connection parameters for accessing the database and press “Ok”.
E) The exportation should end successfully and the tables be already into the database. A proof of the correct exportation is given on the Appendix 1 where a physical data model of all the exported tables is shown in detail.

With this exportation a table for each element is created, but the number of, for example, needed bricks for a wall, is not defined because the table “walls” shows only the dimensions (length, square and cubic meters) for each wall. Therefore, new tables with its conversion rates and its material quantities have to be created for each element that cannot be measured in the units given by the BIM software.

In order to show this special case, for the bidding example a wall has been chosen.
5.5 Start Bidding

Once the importation from the BIM software has been successfully the bidding process can start. The steps to be followed are defined next:

A) Log in into the application and go to “Elements” page.
B) Select from “Elements” list the element you want to start the bidding process, “Wall Bricks” in this example (see Figure 21).
C) Check that all the information is correct.
D) Click the “Start Tender” button (see Figure 22).

With this action an e-mail is sent to each supplier who has the same OmniClass number as the material required. The next step is for the supplier to answer with a bid.

5.6 Make a Bid

If the supplier receives an e-mail that means that a new bidding process in his sector has started. Within the e-mail a personal link is added (see Figure 23) and directs the supplier to an application web page. This page has two main areas: at the middle the material information; and at the right a partially filled form (see Figure 24). In that page the supplier has to check the material information and according to it, place a bid by filling in the empty box for bidding price. Then just click the “Tender” button and the bid is submitted.

The variables in this example are passed through the url, but in a more robust application they should be passed using a combination of cookies and sessions.
5.7 Accept a Bid

When the bids are submitted, the best bid has to be accepted by the user and, by doing so, an e-mail is sent to the supplier with the delivery information and the contractual agreement. To accept a bid, the following steps are needed to be taken:

A) Log in into the application and go to “Bids” page.
B) Find the best bid and click the in line “Accept Bid” button (see Figure 25).
C) The bid is accepted and an order to the supplier is made via e-mail. The size of the order is defined in “order size” and the “number of packages” refers to the number of deliveries needed to accomplish the entire order.

![Figure 25: Accept bids page.](image-url)
Chapter Six: Conclusion

6.1 General Conclusions

This dissertation was set out to explore the lean construction methods and to create a software prototype for Just In Time material delivery. A prototype named Advanced Material Management Application (AMMA) has been defined. The AMMA introduces an e-tendering system to reduce the cost of the materials and an automated inventory manager to handle the on site materials in a more efficient way. The application is based on a logistics by consumption approach or Just In Time, meaning that all the materials that come to the construction site are used. With this application, the materials cost decreases in two ways: the purchase cost is reduced because more suppliers are available, thus giving more options to chose from; and the holding inventory costs for the construction company tend to zero because all that enters on site is used almost the same day.

Within the literature review it is broadly accepted that the lean construction can contribute to decrease the time and cost of construction projects. The implementation of Just In Time is an essential step. Introducing JIT in the construction sector requires a complete change of mind of the stakeholders. The suppliers have to accept more competitive practices such as e-tendering and agree to partner with other suppliers to establish, together with the contractors and project managers, a logistics by planning at an early stage of the project. Changes are also needed for the suppliers on the materials transportation because the transportation has to be handled separately from the materials cost and each project has to be analyzed carefully to implement the milk-run technique, when possible, thus fostering a local suppliers network around the construction site.

Regarding the site manager, a change from traditional methods to ICT is needed to modernize this workplace and to liberate it from repetitive tasks that can be performed by an application such as AMMA, thus having more time to dedicate to solve the site problems.

All these changes are need to be implemented at the same time because trying to implement lean construction by stages is nothing but a bad choice and only when all the activities speak the same language are understandable.
6.2 Application Strengths

The application strengths are defined next:

With this application all the stages from material management (buy, order, store and use) are unified in the same software being able to retrieve any record at any time.

It works with BIM and extracts the information directly from the model; therefore no information is lost or misunderstood. Extracting the model information form BIM eliminates unnecessary steps between phases and less paper-based documentation is needed.

The AMMA is a web-based application and does not use flash, thus it is accessible from every device with Internet connection. It is designed to work and use only free and open-source systems; thus no licenses have to be purchased for its development.

Performing routine tasks in an automatic way reduces the human dependency thereby decreasing the probability of errors. Moreover, the site manager has only to perform very simple operations and wait for the material to arrive on site, hence forgetting about the negotiation process with different suppliers.

6.3 Application Weaknesses

The most significant application weaknesses are defined next:

The BIM model has to have all the elements required for its construction, therefore the level of detail of the model has to be really high and if an element is not in the model then it will not be included in the application.

The ODBC exportation method is static, meaning that all the changes made in the BIM model after the exportation would not affect the AMMA, and a new exportation would be needed in order to update the content of the application. Maybe, the assembly line stage called “design freeze” should be implemented in the construction industry when using lean process.

The application only takes into account the material, leaving the labor and equipment aside. A final version of the application should incorporate the labor and the equipment needed for every element because most of the time one activity needs the same labor and equipment, as they are related.

Although an example is given, a real field test should have been performed, but due to time constrains this has been impossible to achieve.
6.4 Future Research

The logistics field of research regarding JIT in construction is very broad and a lot of work is still needed in this field to standardize the packages sizes and transportation equipment needed when ordering material.

Regarding the application, there are some improvements to be done before it is available, the main ones are:

It should have RFID integration to record real time data incorporating the second main pillar of lean construction, the autonomation. With RFID the material life cycle from its order to its consumption would be better recorded and data obtained with more accuracy. This data would be important to improve the system and adjust the orders to the exact needs of the site.

The suppliers should be weighted according to their reliability and location. Reliability is very important because with JIT the construction site is controlled by the timely delivery of materials. The location and therefore the route to the construction site are key elements for implementing an efficient logistics method such as the milk-run system and perhaps, the use of Google Maps would be a good option to implement and analyze the best route between suppliers and site.

Future research should also be focused on the application of 4D and 5D to applications designed for the construction stage where the model could be represented in 3D and the schedule and resources viewed in an all in one application facilitating even more the site manager tasks. This applied to mobile devices (tablets) could be the game changer needed for the implementation of lean construction.

Although it may seem quite a bit challenging, other industries have already made the move and satisfactory results were achieved. Construction should do it as well and this researcher will pursue the evolution of the construction industry towards a more sustainable activity through the use of twenty first century techniques.
References


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Appendices

Appendix 1 Create an ODBC DSN for a MySQL Database

Here the steps given by Autodesk to create an ODBC for a MySQL Database are given.

A) On the Windows Start menu, click Settings, click Control Panel, click Administrative Tools, click Data Sources (ODBC). The ODBC Data Source Administrator dialog box is displayed.

B) In the ODBC Data Source Administrator dialog box, click the User DNS tab if you want the data source to be visible only to you on this machine, or click the System DSN tab if you want the data source to be visible to others on this machine and on the network. Click Add. The Create New Data Source dialog box is displayed.

C) In the Create New Data Source dialog box, click MySQL ODBC 3.51 Driver, click Finish. The Connector/ODBC 3.51.12 dialog box is displayed.

D) In this dialog box, in the text entry box labeled Data Source Name, type the name that you want to use as the value of the DataSourceName connection property.

E) In this dialog in the text entry box labeled Server, type the hostname/IP address of the machine where the MySQL database server is installed. The default is localhost.

F) You can ignore text entry boxes labeled User and Password. You provide that information using the Fdo UserId and Password connection properties.

G) Pick a database using the drop-down combination box labeled Database.

H) Click OK to close the Configuration dialog.

I) In the ODBC Data Source Administrator dialog box, you see the DSN that you just added listed. Click OK.