The graphical modeling as a support tool for planning and monitoring sustainable construction projects and public infrastructure

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The graphical modeling as a support tool for planning and monitoring sustainable construction projects and public infrastructure

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Abstract: Visual communication through graphical scheduling methods is often the point of failure for the planning and monitoring of construction projects. The proposed chronographic model studies the graphical visual representation of the schedule in the spatial dimension. This model classifies the scheduling entities, especially the activities, the resources and the area of work, into three types of entities. These entity types symbolize the construction operations, establish the relationships between them, and determine the direction of flow of information. Using these entities, the planner can define the graphical approach in order to display the schedule information under diverse, compatible layouts and switch between these layouts. The primary goal is for all stakeholders to have a better understanding of the scheduling logic.

This paper describes the meta-model that is used to structure these entities into classes, define their classification criteria with the visual representation of the scheduling approaches, and infer the relationships amongst them. The use of the Entity Relationship (ER) model to create the meta-model ensures uniqueness and stability. The result is the development and implementation of a meta-model that allows the planner to display the schedule information's under diverse approaches, add/edit entities, organize them into classes and infer their behavior towards each other in order to gain a better understanding of their roles. The validation process is done through the generation of the ER conceptual data model, adapted to the Chronographic construction scheduling approach that embraces change while maintaining consistency and self-validation despite the addition of new entities in classes.

1. Purpose of the research and expected results

This paper presents a meta-conceptual data model as a support tool for planning sustainable construction projects and public infrastructure. The objective of the proposed meta-model is to standardize the development processes of the conceptual and physical data models. The model is based on the Chronographical Classification and Representation Model (Francis 2004; Francis and Miresco, 2006). This paper provides a generalization of the behaviour between the entities resulting from this classification.

The long-term program seeks to implement a web-based solution for the graphical presentation of project scheduling as a support tool for planning and monitoring sustainable construction projects and public infrastructure. The proposed method focuses on the optimization of the modeling data and on the effectiveness of the use of a site layout. The modeling process and the graphical user interface are considered in order to enhance the clarity and ease of reading data, and the accuracy of presented information, as well as to analyse the flexibility and adaptability of the model. The goal is also to involve the user in establishing a solution.

The proposed conceptual framework (Figure 1) is composed of four (4) abstraction layers:

Layer 1 studies the appropriate settings for different project types and specialties and establishes appropriate graphical parameters and modeling approaches.

Layer 2 analyses the visual layout of the user interface and discusses the suitable visual parameters and variables and their associated values (tabular, graphical, colours, shapes, fills, borders, patterns, text, fonts, etc.). The goal is to offer a standard visual protocol for project planning modeling.

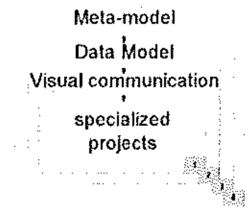

Figure 1: Layered conceptual framework

Layer 3 defines the Physical, Associative, Functional and Measurement entities and conceptual Chronographical approaches to planning and monitoring sustainable construction projects and public infrastructure.

Layer 4 concerns the meta-model. Given the large amount of modeling information to be processed, we need a meta-model that organises construction planning parameters into categories, and then analyzes the behaviour among them.

The present paper studies this fourth layer. The meta-model allows planners to create new planning parameters while automatically deducing their behavior and embracing changes to the existing data systems while ensuring process stability.

Applying this meta-model to construction planning will offer a tool for data system design. This paper proposes a standard representation of construction planning by building a meta-model based on the Entity-Relationship (ER) model of Chen (1983) which then provide physical data models. Codd (1980) and Chen (1983) support a standard which represents the real world based on relational algebra which leads to a physical data model. Therefore the meta-model contributes to the robustness of physical data models of construction planning computer systems, especially those offering a graphical representation.

2. Modeling the data of graphical representation

A study on success and failure factors and performance measures of web-based construction project management systems (Nitithamyong 2006) shows that data quality and reliability are the first preoccupation of professionals regarding system characteristics.
Modeling data is one of the most important parts of development in order to ensure data integrity and validity. There are several tools available for modeling but the principle remains the same: describe entities and the relationships between them. This process is called Conceptual Data Modeling (CDM).
Several data models for project management have already been studied. Hazeyama and Komiya (1994) presented a model database for software project management. This system allows not only for the precedence constraints on the activities but also on workers' schedules. The objective of our model is to share schedule viewing. Even if Kamiya Hazeyama modeling (1994) could be incorporated into our model, our system differs by the introduction of new concepts related to the chronograph display method.
Ji, Moselhi and Alkas (2006) have modeled a system for storing and organizing data on a project to better control projects with ER diagram. This model satisfies database applications like SQL (Structured Query Language) that will generate a suitable display for the chronograph. Indeed, the data model for chronographic display needs to take into account new attributes for the system. The concept of physical, associative, functional and measurement entities is a new level of abstraction. To ease the representation, we need to understand, redefine and adapt the project data model.

Visual communication throughout planning is often the point failure of project management systems. The primary purpose of a collaborative planning system is an understanding of the system by all stakeholders. Thus we believe that the graphical GANTT using precedence logic can hardly meet the graphical requirements regarding screen-size reduction (cell phones, tablets, pocket PCs, PDA, etc.) (Anumba and Aziz 2006; Pena-Mora and Hari Dwivedi 2002). Responding to the demands of display optimization and easy understanding and representation of logic in planning meets the requirements of communication not only between participants but also between the user and interface.
This paper uses a chronographic model to addresses these concerns. The global approach of this model (Francis 2004; Francis and Miresco 2006a, 2006b, 2011) studies the graphic visual representation of the entire project in the spatial dimension. This approach defines the physical entities that symbolize the production tools (such as activity, resource, materials, etc.) and establishes the associative and functional entities (constraint, probabilistic entity, decision point, etc.) and the measurement entities that define the external and internal measurements of entities and the modeling axis. The global approach defines the graphical parameters by laying out schedule information under a diverse, compatible approach in order to schedule and switch views between perspectives. Parameters model the construction operation, establish constraints, and determine the flow of information. This scheduling approach can help managers to share project information in a clear and comprehensible manner in order to facilitate site management and increase productivity.

2.1 The Entity Concept

The goal is to establish a standard in the conceptualisation of this graphical method "to agree on an intellectual framework, in order to create a scientific understanding or abstraction of engineering processes in practice." (Kiliccote, Garrett, and Fenves 1996). The model presents the generic planning element classification (Francis and Miresco 2006). Generic entities (see Table 1) can be classified into four categories: i) *Physical Entities* that represent the production tools; ii) *Associative Entities* that indicate relational constraints; iii) *Functional Entities* that enable the characterization of physical or associative entities; and iv) *Measurement Entities* that designate external and/or internal measuring units.

Table 1 shows the classifications using the approach previously introduced, i.e. management entities commonly used and the entities from the chronographic method.

Table 1: Entities Types

Physical (PE)	Associative (AE)	Functional (FE)	Measurement (ME)
Activities	**Relationships (Reflexive)**	**Constraints**	**Time**
Main, Sub, Task	Finish to Start	Minimal & Maximal Lag	Hours, Day, Week,
Planed, Actual, Projected	Start to Start	Free, total, Independent	
Early, Late	Finish to Finish	or Interference Float	**Cost**
	Internal to Start	External & Inertnal Float	Estimated, Actual, Projected
Resources	Finish to Internal		
Labour, Tools, Equipment	Internal to Internal	**Probabilistics**	**% Progress**
Depart., Supplier, SUB		Time, Cost, Performance	Duration, cost, etc.
	Attributes (Non-Reflexive)		
Emplacements	Complete / Segment	**Decision**	**Quantity**
Store, Wing	X-External Unit	If, And, Or, Xor	Unit, Length, Weight
Store, Unit, Km	Y-External Unit		
WorkShops, warehouse	X - Internal Unit	**Optimization**	**Performance**
Quarries, borrows	Y - Internal Unit	[>, <, =, max., min.]	Time, Cost, Scope

3. Building the Meta Model

The meta-model approach provides a representation of the planning data. Using this approach, all entities with the same type (for instance all PE) are considered as equal. With the meta-model, derived from the chronographic method, only the manager can decide how he will model, display and optimise his schedule. It is possible to display the same type of information using different views in order to optimise the process, or to manage conflictual situations. These features can help to optimize resource utilization for the purpose of sustainable management.

There meta-model represent two types of behavior: i) the *Reflexive* associative behavior: to relate Physical Entities from the same type, as a relationship Finish-to-Start between two activities. This type is represented by an orange diamonds in the meta-model that relate the Physical entity to itself; and ii) The *Non-Reflexive* associative behavior when we connect two distinct Physical Entities types, such as attribute a resource to an activity.

The design and building of sustainable projects is a relatively new and demanding field. New types of entities, graphical parameters and modeling approach elements can eventually be integrated into the planning system. The classification of modeling parameters according to the chronographic method can infer the behavior of the new elements toward all entities regardless of their type. Figure 2 shows the meta-model with the different types of entities, their behaviors and the relationships among them.

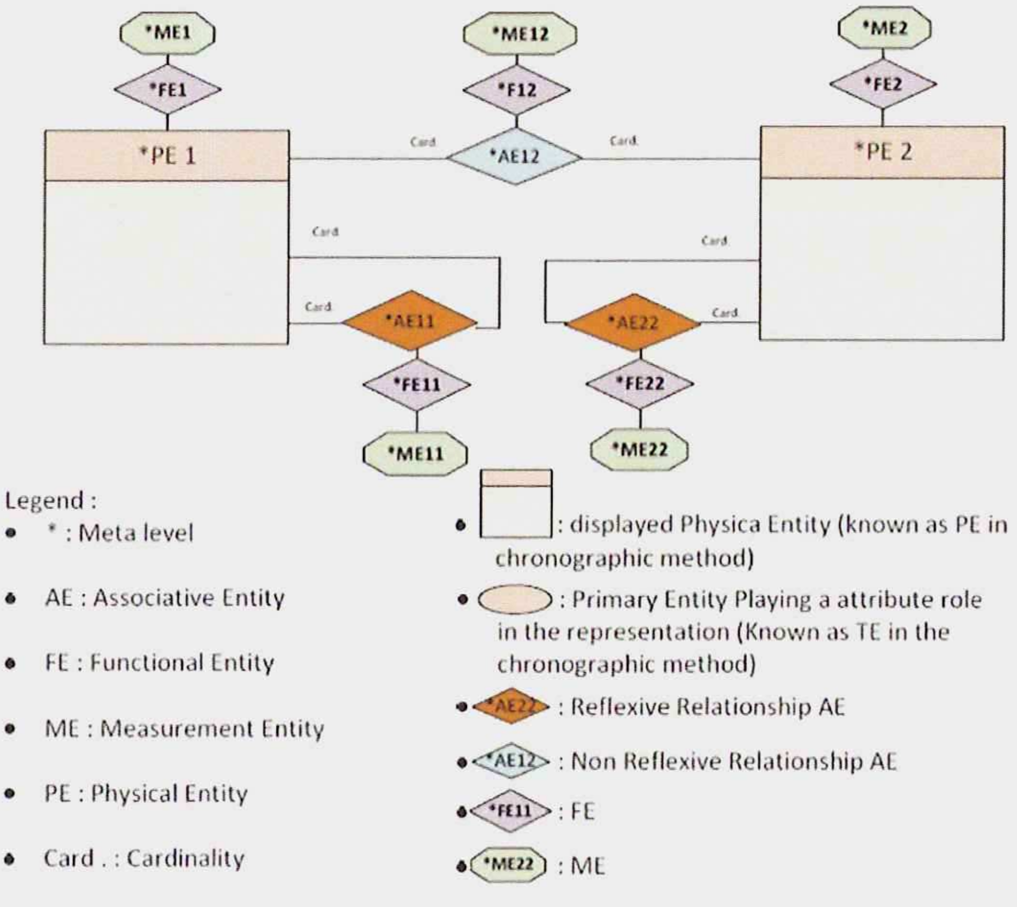

Figure 2: The meta-model

The validation process of the meta-model was conducted at two levels. The first level concerns the stability of the model and the second is related to its applicability. The addition of new elements into the Entities categories allows for the ability to check the stability of the meta-model. Several new elements were introduced into the meta-model, such as hierarchical levels (added to the associative entities) or permanent materials (added to the physical entities); the stability of the meta-model was tested in order to represent these new types of elements without having to modify the modeling concept. For example, the management hierarchy of elements can be applied to either Resources (OBS) or Activities (WBS). The hierarchical type of the physical entity may lead to reflexive relationships between parent and child. This is true for "Resources" and "Activities", and as well as "Work Placement". The meta-model has therefore proved stable behaviour for all tested cases which confirms the first validation.

The second validation, regarding the applicability of the meta-model, is demonstrated in the following case study.

4. Case Study: Testing the applicability of the meta-model on the graphical model for project planning.

In this section we perform the second validation process regarding the applicability of the meta-model for the graphical modeling approach to project planning and public infrastructure. The case study applies the meta-model for the construction of a sewage treatment plant. First, we defined the physical entities were defined that would simulate the construction operation: i) the work breakdown structure WBS, assigned to Activities ; ii) the working areas breakdown structure WABS, dividing the project into zones (Pumping station, Screening, Clarification, Sludge Treatments, Administrative Buildings, etc.), subdividing each zone into different floor levels, and splitting each floor level into specific working areas; and iii) the Organization Breakdown Structure OBS (management, professional and contractor, etc.). These three breakdown structures are presented, with the same concept, as reflexive associative entities, as shown in Figure 2.

Table 2: Rules to generate conceptual data model / number of relationships between entities

Relationships between entities		**PE**	**AE**		**FE**	**ME**
			(reflexive)	(non reflexive)		
PE		0	2	1	1	0
AE	**(reflexive)**	2	0	0	1	0
	(non reflexive)	1	0	0	1	0
FE		1	1	1	0	1
ME		0	0	0	1	0

Table 2 is a symmetric matrix with zero diagonal and establishes the number of relationships between each entity type (PE, AE, FE, ME). Links between entities are established as following:

- Two Physicals Entities (PE) with different types can be linked together through an Associative Entity (AE).

- Two Physicals Entities (PE) with the same type, can be related with reflexive AEs (forming two links), and to non-reflexive AEs (with a single link).

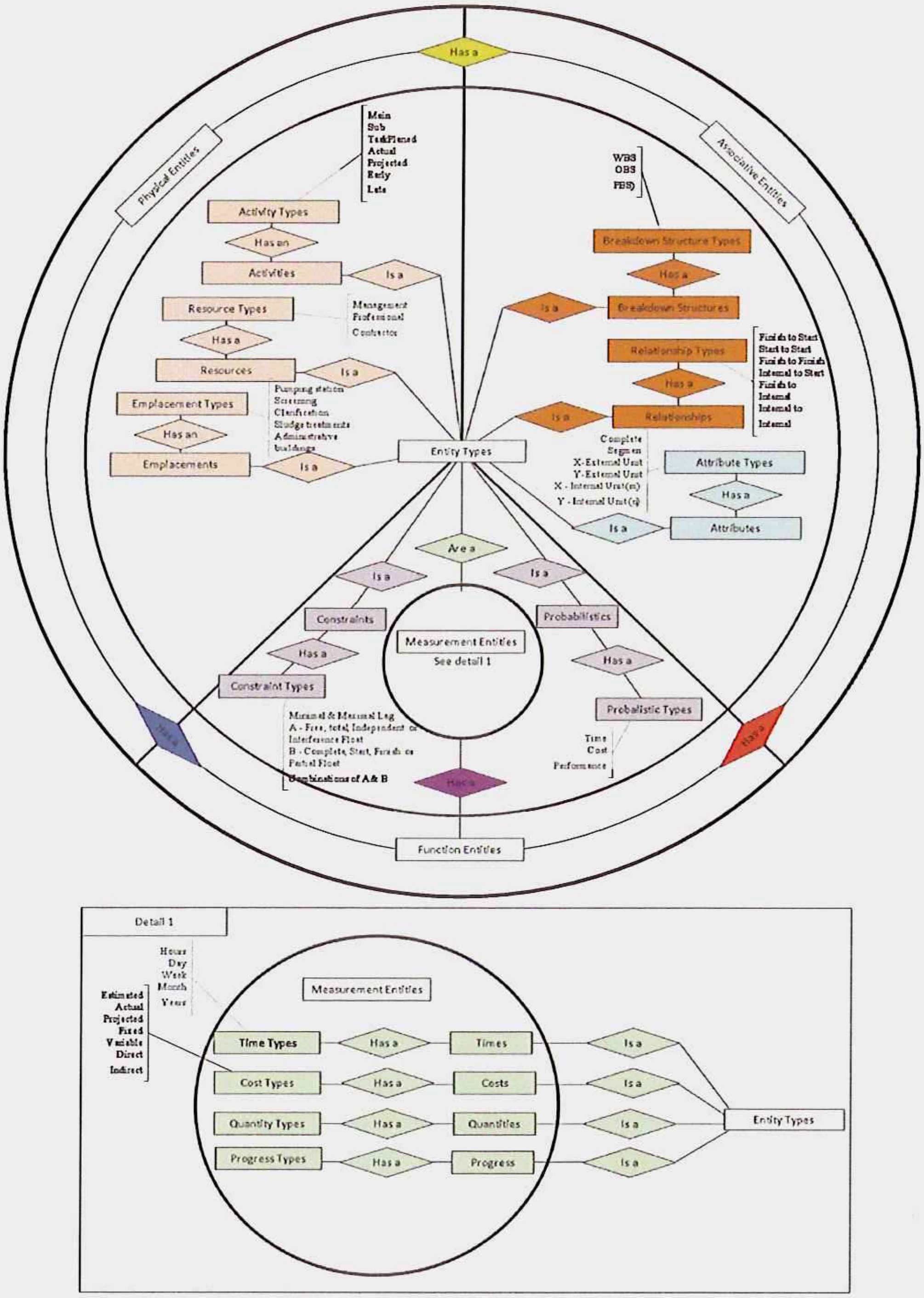

Figure 3: Representation of a two-dimensional skeleton for a non-exhaustive meta-model

- Each PE can be linked to a FE (with a single link) and a ME (with a single link).
- Each AE will operate the relationship through an FE (with a single link) and a ME (with a single link)

By applying the rules defined in this table we can generate the physical data model using the skeleton shown in Figure 3.

The combination of these structures can then validate a larger physical data model adapted to the infrastructure project.

5. CONCLUSION

Simulation and monitoring of planning is a major issue in the construction industry. The increasing demand for interconnection between the site's stakeholders through different types of devices requires a reconsideration of the programming and the data storage choices. The graphical representation of the planning information is an issue of communication and interaction of knowledge and requires new models able to ensure data integrity while maintaining graphical logic representations. The proposed meta-model demonstrates the design of the proposed protocol for such applications. The result is the development and implementation of a meta-model that allows the planner to display the schedule information under diverse approaches, add/edit entities, organize them into classes, and infer their behavior towards each other in order to gain a better understanding of their roles. The validation process of the meta-model was conducted at two levels. The first level concerns the stability of the model and the second is related to its applicability on an infrastructure project model. Involving planners in the modeling process for planning sustainable construction projects and public infrastructure would provide a whole new challenging perspective such as: (i) it would offer a new strategy for structuring the scheduling data graphically, (ii) it would propose graphical solutions for conflict resolution, (iii) it would present the project constraints in a visual, flexible and realistic way, and finally (iv) it would contribute to enhancing the site productivity.

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