BIM-LPS® Integration Case Study in the MEP Sector: Automating Phase Schedule Generation

Maroua Sbiti[1,2], Djaoued Beladjine [1], Abinandana Boodi [1], Lionel Chevalier [2], Karim Beddiar [1]

[1]CESI LINEACT Research unit, France
[2]EQUANS Organization, France

maroua.sbiti@viacesi.fr, dbeladjine@cesi.fr aboodi@cesi.fr lionel.chevalier@equans.com kbeddiar@cesi.fr

Abstract -
The Last Planner System® (LPS®) and Building Information Modeling (BIM) hold strong potential to improve construction productivity, yet their integration at the data-processing level remains limited. Information embedded in BIM models is often insufficiently structured and therefore not directly exploitable for LPS® implementation. This study proposes an approach that integrates LPS® with BIM while leveraging multiple sources of operational project data to automate phase planning. The work focuses on the mechanical, electrical, and plumbing (MEP) domain, which is particularly complex and has been less explored in prior research.

A digital tool was developed to automatically generate time–location schedules by combining tender-phase estimates, execution-phase BIM models, client-defined milestones, and expert knowledge of MEP work sequencing. System requirements were defined through a literature review and surveys with MEP professionals. Installation operations were standardized, and the solution was implemented as a three-tier web application supporting automated data extraction, processing, and visualization for project planning, using tools such as Dynamo Revit, MySQL, Java, and Angular.

Validation on a real project demonstrated clear benefits: the time required for initial planning is reduced by up to one week compared with traditional methods. In addition, automated schedule generation and updates yield a financial gain of 0.91% of project revenue - equivalent to nearly 30% of the planned profit margin - highlighting both the practical value and the economic relevance of the proposed approach.

Keywords -

LPS®, BIM, Lean construction, MEP, Construction Management

1 Introduction

Detailed production planning and control has been consistently emphasized in the Lean Construction (LC) literature as fundamental to overcoming the shortcomings of high-level project plans developed during the preconstruction stage (master plans). Such plans typically provide sufficient detail and time horizons for owner-contractor coordination, but are inadequate for guiding day-to-day construction activities and ensuring reliable project delivery [1, 2]. To address this limitation, LC advocates progressively translating project objectives into executable tasks closer to the point of delivery. The Last Planner System® (LPS®) operationalizes this principle by introducing phase planning as an intermediate level that bridges long-term strategies and short-term commitments, and by incorporating lookahead planning to identify and remove upcoming constraints. Combined, these components enhance planning reliability, stabilize workflow, and improve the predictability of project delivery [3, 4, 5].

Recent research shows that integrating LC and BIM, particularly through BIM-LPS® co-application, further extends these benefits, as BIM supports the rational use of resources (e.g., materials, crews, and equipment) in alignment with the schedule and facilitates improved information flow [6]. This synergy has motivated the development of so-called Lean IT-tools, which are designed to support one or more aspects of the LPS® while providing links to BIM models. Examples include LEWIS [7], which integrates 2D/3D plans, production data, and 4D visualization; KanBIM [8, 9], which enables short-term planning and monitoring with clear task-maturity visualization; and VisiLean [10], which supports multiple planning levels and resolutions, such as phase, lookahead, and weekly planning. VisiLean also provides a mobile interface allowing workers to access task information, update status, and synchronize progress with the BIM model in real time.

Despite these advances, BIM-based production management systems still lack data-level integration between BIM and LPS® [11, 12]. In practice, BIM information is not systematically structured for direct use in LPS®, and object–task links are often created manually during workshops, making the process slow and inefficient. These links also fail to enrich task attributes such as quantities or costs, leaving much of BIM's potential underused. This aligns with findings by Schimanski et al. [13, 14], who note that seamless BIM-LPS® integration requires advanced capabilities such as automatic task generation, cost estimation, and flexible data exchange. Reflecting this need, recent work shows that automating planning and control within LPS® supports 10 of the 11 Lean Construction principles [15].

Parallel to these observations, automated BIM-based scheduling has been widely explored in structural engineering [16]. Early studies, such as De Vries and Harink [17], generated preliminary schedules using component relationships from 3D CAD models and duration estimates. Kataoka [18] expanded this direction by producing multiple schedule scenarios from early design models and construction knowledge templates. More recently, Wang and Lin [19] enhanced BIM with work-package information to address resource-constrained scheduling problems. Yet despite these contributions, a core scientific challenge persists: integrating heterogeneous datasets (e.g., estimates, BIM models, contracts, tenders, and task-sequencing knowledge) into a coherent automated planning process.

Field evidence gathered in this research reinforces this gap. While practitioners show strong proficiency in 3D modelling, a clear need remains to advance toward 4D BIM integration [20]. Tender-stage BIM models are often inconsistent (e.g., oversized vertical ducts or duplicated network elements) and frequently lack standardized codification (Omniclass, Uniclass), making them unreliable for workload estimation or schedule development [21, 22, 23]. As a result, professionals manually consolidate fragmented data (quantity take-offs, estimates, contracts) and create schedules in tools like MS Project or Primavera, relying more on personal expertise than on automated, data-driven methods. This process is time-consuming—about 0.91% of project revenue, a significant cost given a 3% profit margin [23]—and highlights the need for automation in MEP planning, where BIM-based scheduling remains underdeveloped [16].

2 Research objectives and methodology

In response to these gaps, this research aims to advance BIM-LPS® data integration by automating the generation of LPS® phase schedules. It focuses on MEP schedule automation, an area less explored than structural works due to its complexity and interdisciplinary nature [16]. The study moves beyond conventional BIM use by integrating multi-source, multi-phase data, combining project estimation information with execution-phase BIM outputs to detect discrepancies between tender assumptions and execution realities. This enhances decision-making and strengthens alignment between tendering and execution teams. Accordingly, the research investigates how integrating such operational data enables automated LPS® phase schedule generation in the complex context of MEP works, thereby laying the foundation for an optimized approach to managing building information, termed Lean BIM Management.

To ensure both practical relevance and theoretical contribution, the study follows a Constructive Research Approach (CRA). CRA develops innovative artifacts that address real-world problems while informing theory. It relies on abductive reasoning and close collaboration with practitioners [24]. Guided by the CRA framework (Figure 1), the research identifies the BIM–LPS® integration challenge through literature review, and an assessment of MEP scheduling practices and need within the industrial partner, Equans (Section 1: Introduction). Empirical insights were gathered through a survey of 100 professionals and semi-structured interviews with five project managers. The proposed automated planning solution was then designed (Section 3), implemented, and validated through a case study and qualitative feedback (Section 4), from which its theoretical contributions were derived (Section 5).

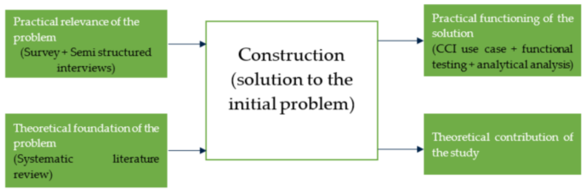

Figure 1. CRA framework and methods used

3 Design and development of the automatic scheduling solution

The system was developed from functional and operational requirements, as detailed in [20, 23], and implemented as a 3-tier web-based scheduling solution. Figure 2 presents the overall framework of the developed artefact. While the framework can guide automated planning in other MEP enterprises, consistent data requirements and algorithms notwithstanding, variations in input sources' structure and availability require careful analysis and adaptation to each organizational context.

3.1 Data sources

The first pillar outlines the primary data sources, including project cost estimates and the execution-phase BIM model, which provide material quantities at the tendering and execution stages, respectively. Cost estimate data are obtained from two sources: quantity takeoff sheets prepared by cost estimators and the final bidding document (client contract) generated using QuickDevis. An initial analysis of both sources reveals key limitations. The QuickDevis file lacks contextual information, such as the location of materials and their associated systems. Instead, it is organized into custom sections based on the client's global price decomposition structure (DPGF), which often results in the grouping of equipment and their associated installation durations without detailed breakdowns. Conversely, the quantity takeoff sheets provide valuable contextual and technical information, including material quantities, locations (building and floor), MEP system assignments, and technical specifications (e.g., diameter, flow rate, pressure). However, they do not include installation durations. Although incomplete, this structured technical data could nonetheless serve as a basis for deriving installation times by matching each article to the corresponding cost database item, using material classification codes and technical characteristics. In case of ambiguity, item codes were assigned in consultation with superintendents. For example, a 315 mm flexible duct may correspond to GNF 0315 (aluminium), GNF I-315 (insulated aluminium), or GNF G-0315 (semi-rigid, non-insulated), with installation times of 0.2 h/m for the first two and 1 h/m for the third, illustrating the impact of incomplete specifications on planning.

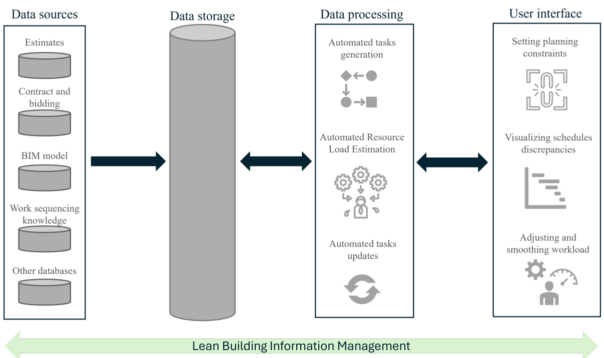

Figure 2. Architecture of the automated planning solution

A similar challenge arose when working with execution-phase BIM models, which often lack sufficient detail, including installation durations and technical specifications needed for direct cost database coding. To address this, a custom Dynamo–Python workflow was developed to link BIM materials to cost database categories, with item codes assigned in consultation with superintendents to resolve inconsistencies and ensure accurate mapping.

Beyond material quantities and durations, the contractual schedule provides the system with project milestones, organized by building level and, where relevant, by specific zones. Finally, the automated scheduling system required formalization of material installation sequences and time allocations, which were captured through expert workshops, converting informal know-how into structured planning knowledge. Previous work by the authors detailed the bill of process for the stainless black steel distribution pipe category (“TAD”) [20].

3.2 Data integration and database architecture

The second pillar consists of a MySQL database, whose conceptual model is illustrated in Figure 3. The database is structured around several entities (yellow blocks) interconnected by associations (blue blocks). For clarity, these entities and associations are grouped into four categories, each corresponding to a distinct data typology and visually delineated by dashed rectangles, within which the previously described data sources are stored. In terms of data integration, BIM quantity take-offs were automatically imported via a Dynamo script, whereas all other data were manually uploaded in Open Document Format.

3.3 Data processing algorithms and workflow

The third pillar is a backend server that represents the central and “intelligent” component of our automatic scheduling system. It handles data processing and employs advanced algorithms to transform scheduling input data into accurate and reliable time-location schedules. Developed using the Java programming language, this layer interfaces with both the database and the user interface, as shown in Figure 4. The data transformation process includes task instantiation by building, level, system type, and superfamily, followed by computation of durations, start, and end dates for the tendering and design phases. Execution dates account for working hours, level availability, and prerequisite tasks. Tasks are first transformed into a graph and topologically sorted using a depth-first search algorithm (DFS) to respect predecessor-successor relationships. The mathematical model described in [20] then computes task durations and dates while estimating required daily manpower.

3.4 User interface

The final layer is the user interface, implemented using the Angular framework, enabling intuitive interaction with the automatic planning tool. Results for the Rennes Surgical and Interventional Center case study are presented in the next section.

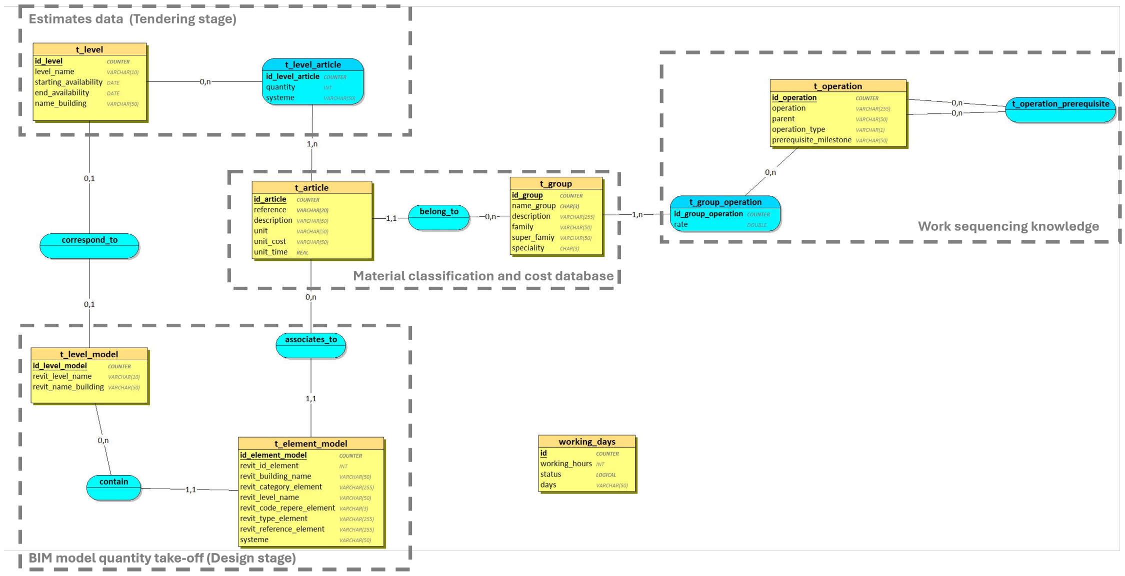

Figure 3. The conceptual model of the scheduling database

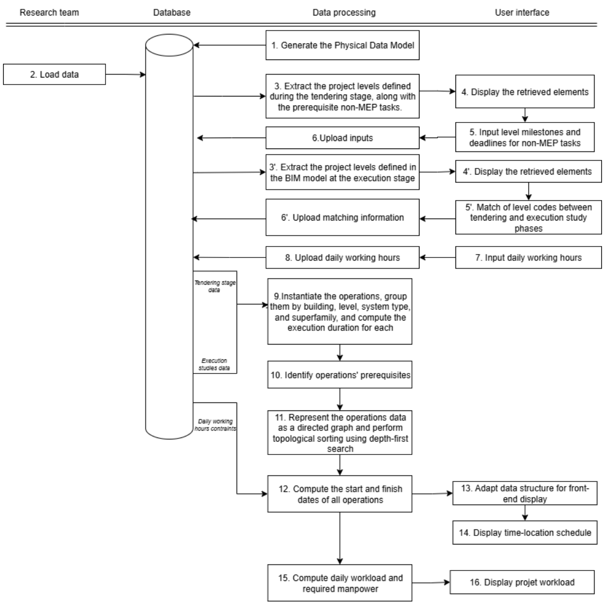

Figure 4. Algorithmic Workflow of the Automated Scheduling System

4 Case study

To assess the practical functionality of the solution in accordance with CRA guidelines, the proposed system was evaluated through a case study with Equans, using operational MEP data of the €20.8 M Surgical and Interventional Center in Rennes. The project involves the construction of a technical platform dedicated to surgery, interventional radiology, and intensive care, consolidating all surgical blocks and interventional radiology rooms of the Rennes University Hospital Center (CHU) in north-western France. Figure 5 presents a 3D view of the project's BIM model. The evaluation comprised two phases: demonstration of core functionalities and validation of results through expert review.

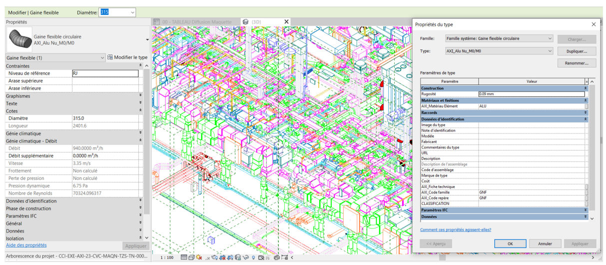

Figure 5. Capture of the case study project 3D BIM model, featuring the properties of a circular flexible duct instance "GNF-G-0315"

4.1 Demonstration of the solution functionalities

The user interface offers functions for inputting scheduling constraints such as level availability dates, preliminary milestones from other disciplines affecting MEP activities, and working days and hours. Based on these inputs, the system automatically generates a time-location schedule, first using cost estimation data and subsequently updated with execution-phase BIM data. Results are visualized through a multi-level GANTT diagram (Figure 6), with cost-based schedules shown in green and BIM-based updates in orange. The "Start PRJ," "End PRJ," and "Duration PRJ” columns show task dates and durations from costing data, while the “EXE Start,” “EXE End,” and “EXE Duration” columns report the corresponding values from the execution stage using the 3D BIM model. Unlike conventional LPS® representations, tasks are not displayed in a time-distance diagram, preserving detailed MEP sequencing and preventing overlaps.

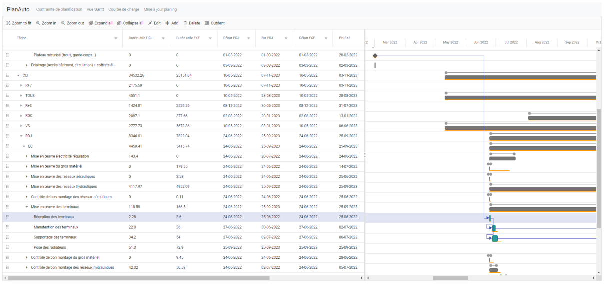

Figure 6. Detailed overview of the tasks required to install hot water system terminals on the ground floor

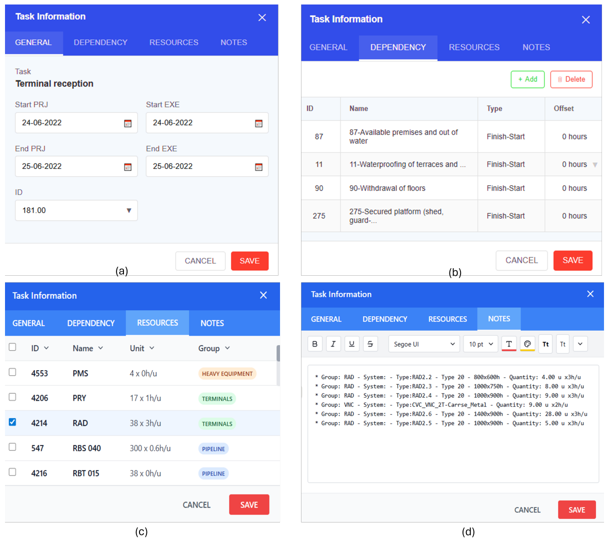

Figure 7. Detailed task information. (a) General information tab. (b) Predecessors tab. (c) Resources tab. (d) Notes tab.

The interface further provides detailed task views through four windows (Figure 7):

- **General**: contains information on task duration, start, and end dates.
- **Dependencies**: lists all predecessors of the selected task.
- **Resources**: lists the equipment linked to this task derived from the quantity surveying data, along with their quantities. These correspond to the items checked in the list.
- **Notes**: lists the equipment linked to this task derived from the BIM model, including their quantities and properties.

Lastly, the system computes daily workload and provides estimates of the required human resources.

4.2 Expert validation results

To validate alignment with user requirements identified in semi-structured interviews, a workshop was conducted with six senior project managers ($\geq$ 20 years of experience, projects exceeding €15 M). The session presented the application’s features and gathered feedback on functionality, gaps, and potential improvements. Figure 8 summarizes functional coverage and participant feedback.

A post-workshop questionnaire evaluated the solution’s utility and reliability through seven key questions addressing problem relevance, current applicability, usefulness for construction planning, result accuracy, computation time, functional coverage, and willingness to test the solution on a pilot site.

Participants recognized the solution’s relevance; however, two-thirds expressed concerns regarding calculation accuracy, potentially due to past negative experiences with automation, a preference for manual processes, or resistance to change. Eighty-three percent found processing times reasonable, and 67% indicated willingness to test the tool on live projects.

5 Discussion and analysis

Although planning automation is not a new issue, this study offers several significant contributions.

First, it addresses the automation of MEP work scheduling, an area that has received considerably less attention than structural works [16]. The relative neglect of MEP disciplines can be explained by their inherent complexity, as they involve highly interconnected systems installed in confined spaces and require coordination among multiple subcontractors. These challenges, combined with the dynamic and uncertain nature of construction projects, make the planning and control of MEP works particularly critical.

Second, the proposed solution capitalizes on operational data from multiple sources beyond the BIM model alone. This distinguishes it from previous research efforts, which often rely exclusively on BIM data [17, 18, 19]. However, the study also highlights key challenges encountered in construction projects, notably data incompleteness and heterogeneity. Data incompleteness stems from the lack of exhaustive equipment descriptions in both costing sheets and BIM models, which hinders accurate identification of corresponding equipment codes in cost databases. To improve the reliability and efficiency of the proposed au-

Category	Functionalities N°	Functionalities Description	Coverage level	Evaluators feedback
Planning constraints	1	The system must enable the configuration of working days and off-days.		The user must be able to specify whether work occurs during the day or night to ensure accurate labor cost calculations. The user must also be able to declare shutdown periods and labor holidays.
	2	The system must allow the configuration of client milestones by building, level, and zone.		Milestone declarations for zone availability were not implemented due to the inconsistent completion of the zone field by estimators in the estimate data.
	3	The system must allow the definition of zones to group building areas, thereby grouping the operations associated with those areas.		This feature was not implemented due to the lack of data about building areas and zones in estimates.
	4	The system must support the configuration and integration of tasks dependencies from other work packages into the MEP schedule.		Deadlines for prerequisite tasks of non-MEP trades must be configurable at the building, floor, and zone levels.
Initial generation of schedule	5	The application must be capable of automatically generating an execution schedule.		It was recommended to increase the pace of work over an entire work sequence (by increasing resources) if the milestone is exceeded with a single resource instead of only constraining the end date for completing the last task in the sequence. This will help smooth the load over the entire project duration. This feedback involves a major change in our mathematical model for calculating task start and end dates.
	6	The execution schedule must be visible from the application interface in the form of a GANTT chart.		
	7	The GANTT chart to be configurable with a resolution of day, week, or month.		
	8	The system must enable filtering tasks by localization, system type, group of equipment, and article code.		It was recommended to add a filter by resource and by customizable fields. During development, tasks were grouped by geographic area and system to enhance readability. Thanks to this grouping, we have limited the GANTT chart to 300 lines. Without this grouping, displaying tasks for each article would result in thousands of lines. Details about the articles required for each task are available through a task details panel
	9	The user must be able to access detailed information about the articles required for each task, including the article code, quantity, unit installation time, and manufacturer.		Integrating the diameter and section characteristics of pipes and ducts into the article details would be beneficial.
Workload estimation	10	The application interface must show an estimate of the resources required to complete all tasks on a weekly basis.		It would be interesting to add filters to the display workload curves by level, zone, and by resource.
Schedule update	11	The schedule generated from estimate data can be compared with the one derived from BIM model data to identify potential material discrepancies between the estimation and execution phases.		Visually highlighting significant discrepancies between estimate and execution schedules using a color code is an avenue for improvement to consider.
Schedule modification	12	Other prerequisite tasks or constraints about areas availability may be added during the creation of a new project or modified later to take into consideration project adjustments.		Adding tasks, modifying durations and dates of existing tasks is possible via the tool. However, it does not result in a modification to successor operations. Addressing this functionality could support managers in manually integrating project changes, considering the dynamic nature of construction, while also identifying deviations from the initial plan and assessing their impact on both the schedule and workload. It is important to keep traceability of the history of modifications made to the schedule.
	13	The user must be able to modify the theoretically calculated duration and resources assigned to each task.		
	14	The user should be able to modify the scheduling of tasks.		
	15	The system must enable the assignment of human resources (individual names) to each task.		
Data sharing	16	Print and export the schedule to MS Project for more flexibility of use and the possibility of sharing data with the client, subcontractors, etc.		

Figure 8. Coverage of User-Specified Functionalities and Project Manager Feedback (green: functionality fully developed, yellow: partially developed, orange: not developed, purple: new functionality identified)

tomated scheduling system, it is therefore essential to enhance the level of detail in these data sources. At present, this limitation restricts the full deployment of required functionalities and constrains the scalability of the solution. Consequently, rigorous data capture, codification, and preservation from the early project phases are required to fully realize the potential of the proposed planning approach. In addition, the adoption of standardized classification systems such as Omniclass or Uniclass could help reduce semantic incompatibilities between data produced by different actors and project phases.

Third, the research formalizes MEP planning know-how through expert workshops. However, the manual and explicit modeling of each material's operations and dependencies proves to be costly and labor-intensive, which may limit scalability when extending the system to new material categories. A promising direction for future work is the automated acquisition of planning knowledge from existing project records, such as historical schedules, BIM-based process data, technical specifications, and execution reports. Recent studies have demonstrated the potential of sequential machine learning to learn dynamic work templates from past schedules, of pattern-recognition methods to identify recurring process logic in BIM-based schedules, and of natural language processing techniques to extract structured knowledge from construction documents. Taken together, these advances suggest that part of the sequencing knowledge currently captured through expert elicitation could in the future be inferred automatically from accumulated project data, thus reducing setup cost and improving transferability across new material families [16, 25].

Fourth, the proposed automated scheduling application streamlines the project planning process by rapidly and effectively processing complex datasets. When input data are complete, the solution can save an average of one week of manual work per project manager, thereby freeing time for higher-value activities such as decision-making and problem-solving. Beyond these time savings, the economic impact is equally significant: automation generates a gain of approximately 0.91% of project revenue, corresponding to nearly 30% of the targeted profit margin (3%). These estimates were developed collaboratively with domain experts using average project data, reinforcing both their credibility and practical relevance. To further enhance its contribution, the application should be extended to the remaining phases of the LPS®, including lookahead planning, weekly work planning, and progress monitoring. The latter could itself be automated using advanced techniques such as unmanned aerial vehicles (UAVs) or real-time location systems (RTLS) for data capture, as well as 3D digital imaging and computer vision algorithms for progress measurement [26, 27].

Finally, this work aligns with broader objectives related to ensuring data continuity throughout the construction project lifecycle, thereby paving the way for more efficient building information management. A significant avenue for future research lies in expanding the automated planning tool to involve additional project stakeholders, including actors in design, procurement, manufacturing, logistics, and commissioning. This evolution entails harnessing large volumes of data from diverse operational sources, which requires the implementation of data warehouses (Figure 9). Such data warehouses are supplied with information generated by multiple operational software systems across project stages, enabling reporting, data mining, and strategic decision-support analyses [28]. This approach introduces a new perspective on lean building information management, referred to as *Lean BIM Management*, and contributes to the emergence of a new era in Lean Construction characterized by intelligence and interconnection between machines, humans, and materials - an evolution described as the *Smart Lean era* by Demir [29].

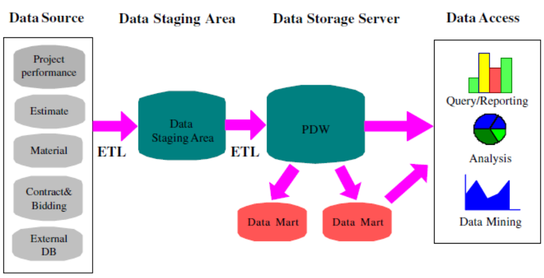

Figure 9. Architecture of a construction-project data warehouse [28]

6 Conclusion

This study aimed to enhance the integration between the Last Planner System® (LPS®) and Building Information Modeling (BIM) at the data-processing level. The main contribution of this work is the development of a web-based application that automatically generates time–location schedules for MEP trades by leveraging multiple data sources, namely cost-estimation data and BIM model information.

Following a Constructive Research Approach, the paper first identifies the planning problem and reviews its theoretical background, before detailing the architecture, input data, and user interface panels of the proposed automated scheduling solution. Real project data from the Rennes Surgical and Interventional Center case study are then used to demonstrate the practical functioning of the system. In addition, an analytical evaluation conducted through focus groups highlights the utility and relevance of the developed application, despite some initial and largely unfounded skepticism regarding the accuracy of automated planning calculations.

Finally, the study discusses the theoretical implications of the proposed artefact, laying the foundation for an effective approach to building information management, referred to as *Lean BIM Management*. Building on this foundation, the paradigm opens avenues for future developments through the integration of data from multiple construction stakeholders into centralized data warehouses. Such integration would ensure data continuity across the entire project lifecycle- from design and procurement to manufacturing, logistics, construction and commissioning- thereby significantly enhancing project management practices and data utilization within the construction industry. This progression ultimately supports the emergence of a Smart Lean Construction era, characterized by greater intelligence and stronger interconnections among data, actors, and processes.

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