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Competitive Construction Management of Microelectronic Facilities

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Abstract
The paper presents key drivers of construction management in highly competitive semiconductor construction projects. The growing volatility of the global chip markets, the cost-intensive production, fast-track construction and GMP-contracts increase the risks of investments for design-build contractors significantly. Therefore, high innovative and complex process technology requires an integrated process-related approach for construction management to identify risks and manage components in construction successfully.

The paper illustrates the scanning, planning and implementation phase of two 300 mm wafer facilities. The base-build construction for a wafer fabrication with a total volume of 1.1 Billion US$ was recently completed within 18 month. It will be emphasized generic criteria for evaluation of core competences and resource allocation. The identification of main technical risk such as soil conditions, high level of variation, complex interaction of civil, mechanical and electrical disciplines, logistic flows and procurement interfaces for the cost evaluation and the overall performance is shown.

Keywords
Construction Management, Information Management, Digital Construction, Semiconductor Fast-Track Projects

1. Introduction

The emerging microelectronic market focuses on new qualities such as time-to-market and high network logistics for the construction process. Companies are faced to develop core competences and skills in fast time. This requires a comprehensive construction management system in the entire value chain with major respect to fast-track construction, outsourcing and strategic alliances. However, the advanced design should focuses on a simple, modular and flexible structural system to generate optimized logistic flows. This demands intelligent segmental pre-cast system, standardized components and operation research models to control and reduce technical risk. For instance, innovative 4D strategic information system (SIS) could be deployed to facility efficient controlling of complex construction sequences. The development of process-related approaches helps to improve the key performance of the construction costs.
The high innovative and complex wafer technology requires a more integrated approach of structural components and process functions. For instance, the lithographic process with steppers demands extreme dynamic conditions for the inner structure. Particularly, the structural dynamics of the entire waffle table induced by the soil-structure interaction, operator and hook-up are quite sensitive to the wafer process. The identification of integrated approaches will improve the key performance of the construction process, optimizes the cost and reduces the technical risk potential.

2. Construction Technology

2.1. Base-build infrastructure and process technology

The entire process technique is divided into the real process and the base-build and hook-up technology. The process technology is highly innovative and will be provided worldwide by a few specialized suppliers. The base-build is a standard technology and generally includes basic mechanical, electrical and process-related equipment such as boiler, chiller, cleanroom, chemical and HVAC systems.
The cleanroom forms the heart of each semiconductor process. The filtered quasi-laminar airflow has a velocity of approximately 0.40 m / sec. The climate conditions are limited to a temperature of approximately 21 degree Celsius, a humidity of 50% and an overpressure of about 30 Pa.
Its cleanroom class according to US standards defines the measure for the cleanroom quality. The used class 1000 means 1000 particle with a diameter of 0.5 µm per cubic foot. This requires an air exchange of 80 times per hour for the total volume of 20.000 cubic meters.

2.2. Construction performance

Traditional manufacturing facilities are designed with priority on the optimal and economic consumption of materials based on the geometry and load only. The highly competitive semiconductor market introduces new qualities for the construction process. It requires a comprehensive design with major respect to the total time of base-build construction. Due to the relatively low percentage of construction cost of approximately 6% on the total volume of investments, the design focuses on a simple, modular and flexible structural system and an optimized logistic flow. This demands intelligent segmental pre-cast system, standardized components and operation research models. Figure 1 shows the digital model of a recently completed Greenfield project. The time-to-market criterion leads to a fundamental change in the approach for design and opens the field for new materials even such as expensive fiber-reinforced-polymers (FRP) and smart systems.

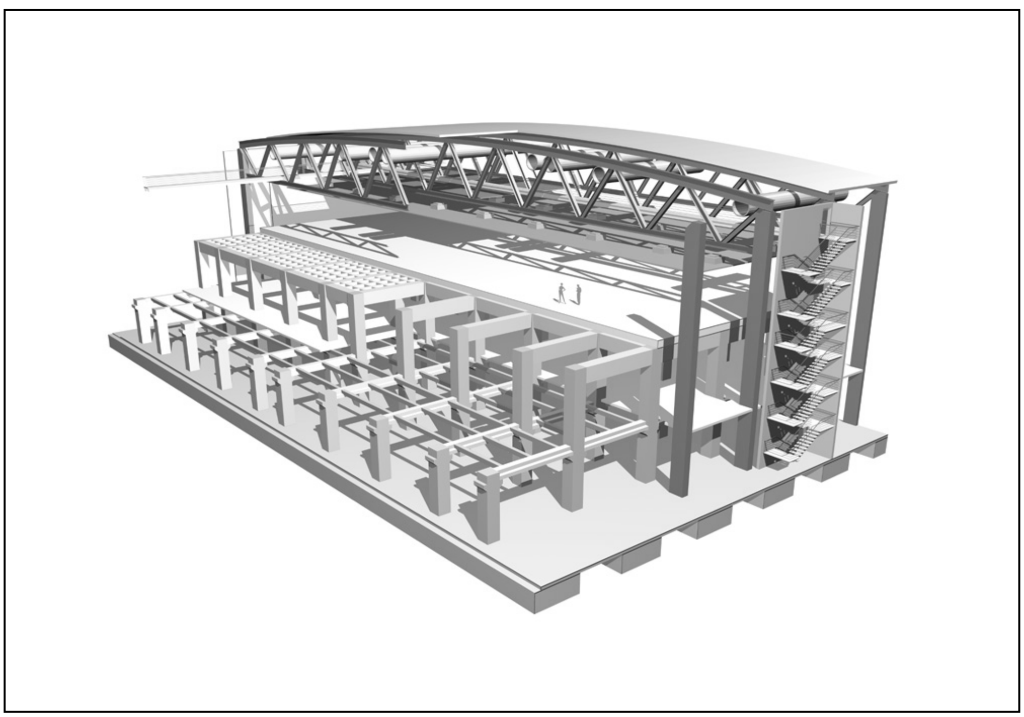

Figure 1: Shell structure of a Semiconductor Greenfield Site

Experiences of two 300 mm facilities designs recently constructed in Germany will be basis for this paper. The base-build construction for a wafer fabrication with a total volume of 1.1 Billion Euros was recently completed within 18 month. It will be emphasized on some features such as vibration control, clean room thermodynamics, fast-track logistic flows and environmental contamination policy. The risk assessment of GMP-contracts for semiconductor facilities will be a further important feature of fast-track projects.
Most demanding issues in the design are the vibration-sensitive process tools. Designing and operating microelectronic manufacturing facilities are carried out on the basis of generic vibration criteria (Eibl 2004). The photolithographic process with steppers in the wafer production requires the extreme vibration specification of class VC-E for the waffle table structure. This limits the root-mean-square (rms) velocity on the waffle table level in the vertical and two horizontal directions to 3 µm / sec in the frequency range between 8 and 80 Hz. The criterion is based on one-third octave band vibration velocity spectra due to vibrations dominated by broadband or random energy.
It has been found in various studies that while equipments and people may exhibit maximum sensitivity on constant velocity curves.
Three main induced excitations are crucial for the waffle table structure and subsequently for the production process. Particularly, the base, operator and process excitation affects the dynamic behavior on the waffle table level.
The separation of inner and outer structure minimizes the environmental impacts such as turbulent winds and snow loads.
It is obvious that contractual guaranties for such extreme vibration criteria are major sources for construction risk.

3. Strategies for Construction Management

3.1. Principles of competitive CM

The construction management of microelectronic facilities comprises the components of risk management, project financing as well as innovation and value engineering throughout design and construction. A competitive construction management in the semiconductor business requires:

- Development of fast-track project financing structures
- Integrated risk management system for allocation and mitigation
- Standardized components and segmental construction of the structural shell
- Pre-fabrication and partial automation of the construction process
- Digital construction management
- Focus on value engineering
- Optimized procurement procedures and Just-In-Time logistics
- Focus on client needs – high flexibility during design and construction

Semiconductor facilities projects are characterized by high complexity and a broad range of uncertainty due to its multi-functional interactions in a fast-track period. Likewise, the high financial investment in a short-term design-build contract creates a significant risk potential in engineering design and construction. This is only partially comparable with manufacturing facilities in the automotive or chemical industry. Technical risks are controllable up to a certain limit (Macomber 1989, Tidd, Bessant and Pavitt 2001).
The term risk has certain definition depending on the use in technical or financial fields. Value at risk defines the maximum loss of the portfolio in a certain period with a confidence level. Risk is a measure for the value of the danger of loss. It can be quantified by a product function of maximum losses multiplied with the probability of losses. Project risk is the exposure to the variability in the outcome of the project. The variability is usually measured by the variance of the distribution.
It can be differed between real, latent and potential risks. Real risks as process-immanent are already present at the time of analysis and can be identified and accordingly considered in the contract. More

complex are latent risks that are existent but obviously visible. Potential risks can probable occur but may be more complex than real risks in the evaluation of the probability.
Often mentioned is the difficulty to estimate a relationship between financial efforts for risk management and relating project success. However, in many cases the monitoring of project tracks, as part of a forecast indicator and pro-active action can be also beneficial to control information flows.
Strategies for risk management should facilitate to mitigate or allocate these risks potential. With respect to the downsizing of the construction industry in the US and Western Europe, certain risk have to be accepted.
However, what makes risk assessment so difficult in project work? The determination of a worst-case scenario with relating losses is often easy. Nevertheless, the evaluation of the comprehensive probability of failure and the interaction of single risk events are values with major uncertainties. The well-known straightforward procedure will be followed for a semiconductor facility.

3.2. Digital construction management

A new approach to develop and control construction processes are the deployment of digital construction management tools (Slaughter 1998, Eibl 2002). Stanford University (Liston, Fischer and Winograd 2001) developed a 4D model, which links 3D CAD drawings with a construction time schedule. This allows the real-time visualization and simulations of the entire construction process. The benefits are a better understanding of multi-functional interfaces, a minimization of design faults and an operation research-based optimization of construction sequences (Hillier and Lieberman 1995). It should be stressed that such tools do not only provide a one time optimized technical solution. Actually, the power of such systems is that they could be used to control in real-time often-disturbed construction operations. Figure 2 illustrates the components and input parameter of a simulation program for a real-time competitive construction management.

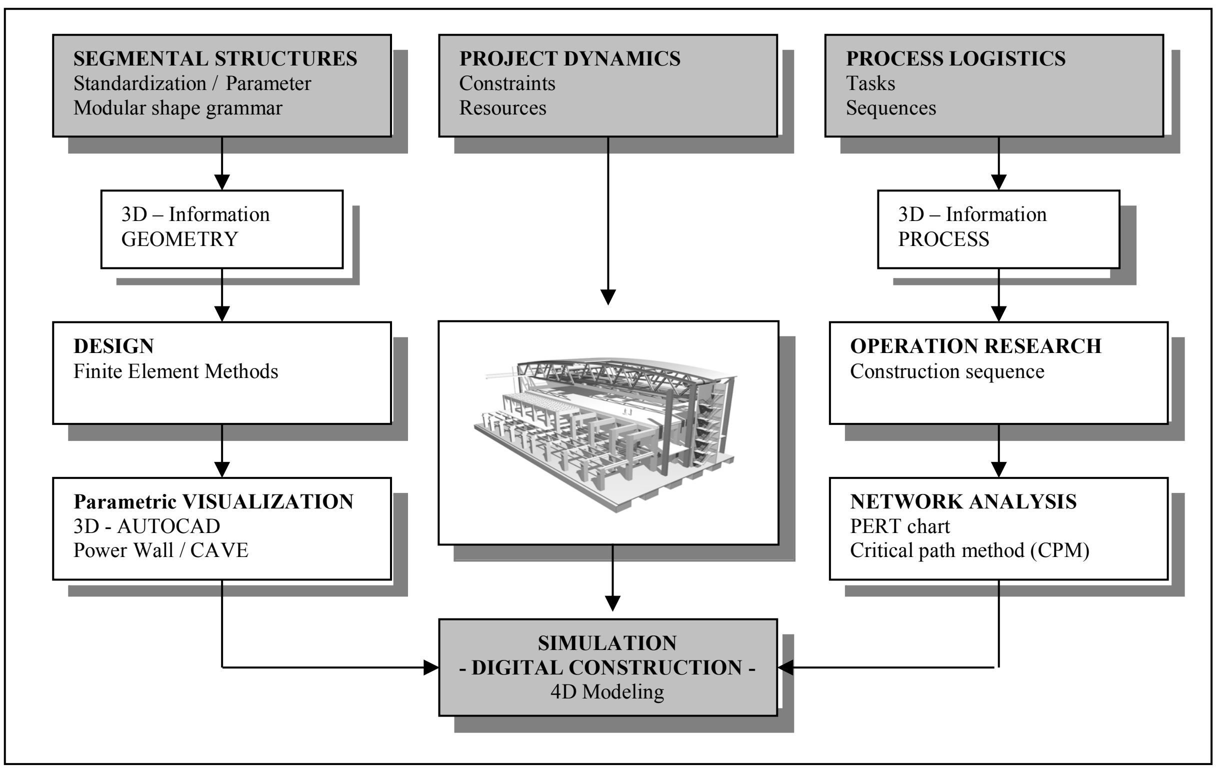

Figure 2: Data flow for digital construction

These kinds of systems are not simple visualization tools, but hierarchical, interactive and parametric 4D software systems.

4. Construction Methodology of Fast-Track Logistics

On the worldwide volatile chip market, the time-to-market is the crucial criterion for the semiconductor industry. This affects authoritative the entire value chain from engineering design to implementation of microelectronic manufacturing facilities. Key driver in this construction process are a modular shape grammar and an integrated fast-track approach (Howe 2000).
The fast-track model splits up the design, procurement and construction phase into process clusters in order to reconnect direct dependent process parts of design and construction. The benefit is a significantly shortened overall schedule. However, this kind of fast-track approach consist major risk potential due to the increase of interfaces and complex dependencies between single tasks (Macomber 1989, Bommeli 1999, Eibl 2003a). It requires more flexible and multi-disciplinary resources.
Figure 3 illustrates a typical construction sequence to erect pre-cast columns, slabs and waffle table elements with several mobile cranes and one heavy load crane.

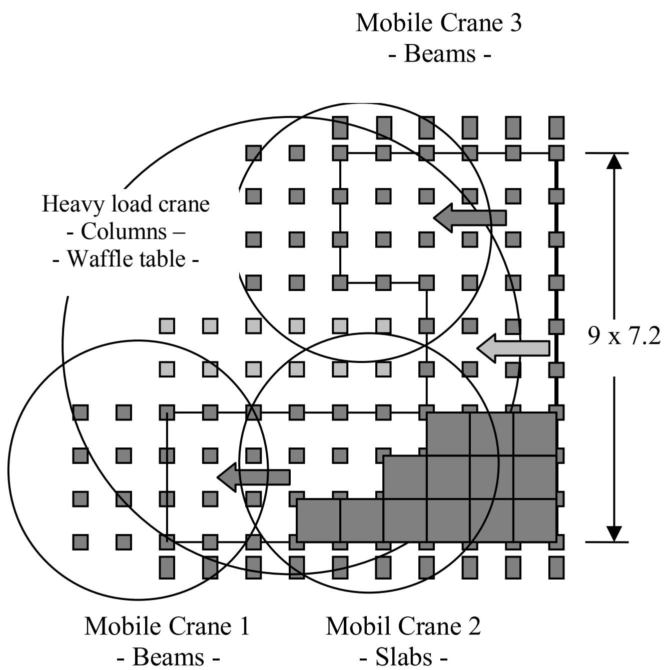

Figure 3: Pre-cast logistic sequence

With respect to the restricted construction site, the logistic played the important role in this fast-track project. The term logistic does not only mean the typical construction sequences but also the infrastructure works and the supply and launching of the process tools.
One key element of the fast-track construction is the Just-in-Time (JIT) logistic of the material suppliers. Therefore, the deployment of pre-cast structural members does not only enhance the construction sequence, it also allows a Just-in-Time production within the supply chain. The entire construction consists of a pre-cast elements completed by in-situ shear walls and steel girders.

5. Conclusions

The present paper focused on crucial issues in the competitive construction management of semiconductor facilities. It outlined the importance of modular pre-cast systems and Just-in-Time logistics for fast-track construction sequences. Despite well-known qualities like optimized structural, the construction of microelectronic manufacturing facilities introduces the construction performance and comprehensive risk management as a competitive issue. Particularly, a new development of digital construction management tools opens best-practice opportunities in engineering and construction for the future.

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