BRIEF REFLECTION ON IMPROVEMENT OF DESIGN PROCESS EFFICIENCY IN BRAZILIAN BUILDING PROJECTS

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ABSTRACT

This paper starts with (i) an introduction on building construction sector design process main characteristics and (ii) a presentation and discussion on its efficiency problems. The Concurrent Engineering concept as a tool to improve this process, approximating it to lean construction approach is introduced.

It also describes a case study on a 22 companies group quality program. This group includes building construction companies, as well design offices, which are implementing some design process changes.

The paper ends up proposing a building design process methodology, based on the concurrent engineering principles.

KEYWORDS

Building design, design flow management, concurrent engineering, lean construction.

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INTRODUCTION

Like in other industries, in building construction, design plays an essential role in the efficiency of productive processes and in the production of value to the clients. Brazilian building companies designs have been seen as a secondary process and normally are addressed to an autonomous designers, hired by service's price criterion, preponderantly. These designers, in their turn, tend to concentrate themselves in the development of their own design specialties, without considering the relation with to other specialties, the building itself and the developing company.

Therefore, the design process is characterized, preponderantly, as a sequential conversion view[4], that transforms the information from technical standards and law developers and other design specialties into solutions and product specifications (figure 1). Those solutions support the following stages design process, in such a way that the building construction ends up by adding some values to the clients.

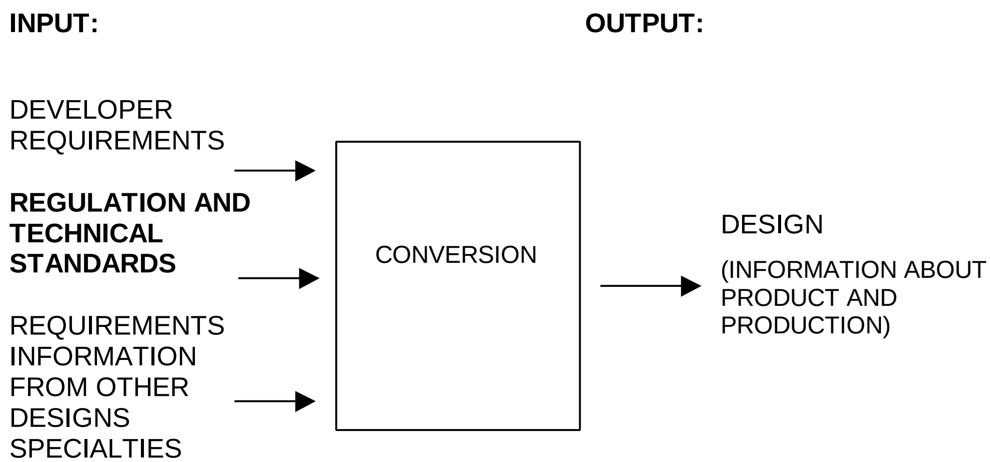


Figure 1: Design as conversion of information and requirements

Considering that in the conversion view very little attention is given to the activity flow of the design (flow view) and to the roles of the design specialists to add value to the product and, as result, value to the client (value generation view), it is very important to discuss how to improve the design process under this viewpoints (Koskela and Huovila 1997).

The present work, based on case studies of Brazilian building construction companies and design offices, presents some analysis and preliminary conclusions on design process redefinition, based on concurrent engineering and lean construction concepts, emphasizing a flow view for this process.

4 The detailed characterization of conversion view, flow view and value generation view can be seen in Koskela (1992) and Koskela and Huovila (1997)

DESIGN PROCESS IN THE BRAZILIAN BUILDING INDUSTRY

The design process in the building construction is performed by several design specialties (architecture, structures, building systems, etc) that develop solutions with increasing level of details. Consequently, the process occurs through different stage successions, where the freedom of decision among alternatives is replaced by the maturity and development of the solutions taken.

Another design process characteristic is that it is mainly concern with the definition of the product design, without considering the characteristics of the solutions and their consequence to the production.

The specifications and details of the product, frequently, are defective and uncompleted, being solved during the building process, when the team ends up determining certain characteristics of the building that were not foreseen in the design.

It is also verified in the building design the existence of a hierarchical relation between the architects and all the other design specialists. According to Melhado (1997), the present technical standards, as well as the institutional texts dealing with this matter, consider the architecture design responsible for the direction to be followed by structural design, building services design, and so on.

After buying the land, based on the definition (by the developer) of the enterprise characteristics, an architectural scheme design is developed and presented for examination by the government proper agency. This allows the necessary financial funds request and the enterprise market release (i.e., the sales beginning).

Usually, only after launching stage, other designers are hired. Therefore, the performance of several design specialists involved in the process does not happen simultaneously and the design is elaborated without the effective contribution of all its participants.

Furthermore, it is observed, on one hand, that, during the design development, the building company and users participation almost does not exist. On the other hand, the developers' influence is quite significant.

The current problems involving integration among building project agents lack can be illustrated by a case-study (Baía 1998) which shows as some of the major difficulties and problems endanger the management of the design process. This research also highlights that the results of this kind of management are: (i) low level of design offices compromise related to the strategy and purposes of the contractor (aggravated situation because of the lack of strategy of the product from the contractors); (ii) absence or inadequate co-ordination of the design process; and (iii) the information exchange between the design office and the building site itself lack.

The work of Cole (1990) upon that of Koskela et al. (1997) mentions that "the most significant causes of design problems are poor briefing and communication, inadequacies in technical knowledge of designers and a lack of confidence in preplanning for design work."

Based on what was previously presented, it is possible to state that the flow model and oriented to the interactivity between stages design process could provide great efficiency to the design and to the building construction itself, besides contributing to the value adding to the clients.

DESIGN FLOWS

In order to improve the design process and its flow performance, it was initiated, early 1997, in São Paulo Brazil, the Civil Construction Design Development Quality Management Program, supported by a number of constructions and design sector agencies, as: (i) SINDUSCON – SP (Sindicato Associação dos Construtores do Estado de São Paulo - Patron Union), SINAENCO (Sindicato Nacional de Empresas de Arquitetura e Engenharia Consultiva – Professional Union), ABCE (Associação Brasileira de Engenharia e Consultoria Empresarial - Professional Association), IAB (Instituto dos Arquitetos do Brasil – Professional Institute), AsBEA (Associação Brasileira dos Escritórios de Arquitetura – Architect Officer Association). This program has been developed and operated by a consulting firm - CET (Centro de Tecnologia de Edificações) - which works on a (i) design firms quality management specific methodology development and on (ii) a solution for design activities flow, characterizing each activity responsibility and the dependency relation between them.

Twenty-two firms participate on this program first turn: 6 (six) architectural design offices, 4 (four) structural design offices, 2 (two) building system design offices and 10 (ten) development and construction companies.

These design offices and building companies discussed the design process flow, identifying which are the major aspects that affect its quality and efficiency.

As a result of these discussions the technical development activities flow was divided into seven great stages. Based on these, a stage strategic planning was elaborated (Figure 2.)

The stage I consists on the project planning aiming, among other things, to verify the viability of a determined product according to the market's demand.

The stage II, named "conception of the product", characterizes the product forms, geometry and constructive processes. In stage III, the development of the product occurs, and it is subdivided into five sub-stages: (i) scheme designs; (ii) permits design (specific design to get regulatory approval); (iii) "pre-executive" design; (iv) executive design; and (v) production design. In stage IV, the design "as built" is developed, and finally, at stage V, a final client's satisfaction assessment is performed.

Nowadays, this design technical development activity flow is still being discussed, with certain disagreements between architecture companies, the engineering designers, building companies and developers, on aspects like the ones concerning to each stage name and aim, specially during the product development (stage III).

This seven big steps oriented a design process flow detailed subdivision, presented by CTE (1998), allowing design offices and contractors to better identify the activities related to their professional fields, as well as, a discussion on the activities developed by different design process agents links.

The participating contractors are using the activities identified in their work field to subsidize design standardization and elaboration, approaching to quality management and, in many cases, searching for ISO 9001 certification.

One of the greater advantages of designs flow developed by this program is that the design is understand as a broad and large process that starts by strategic planning and ends at building final users and consumers satisfaction assessment.

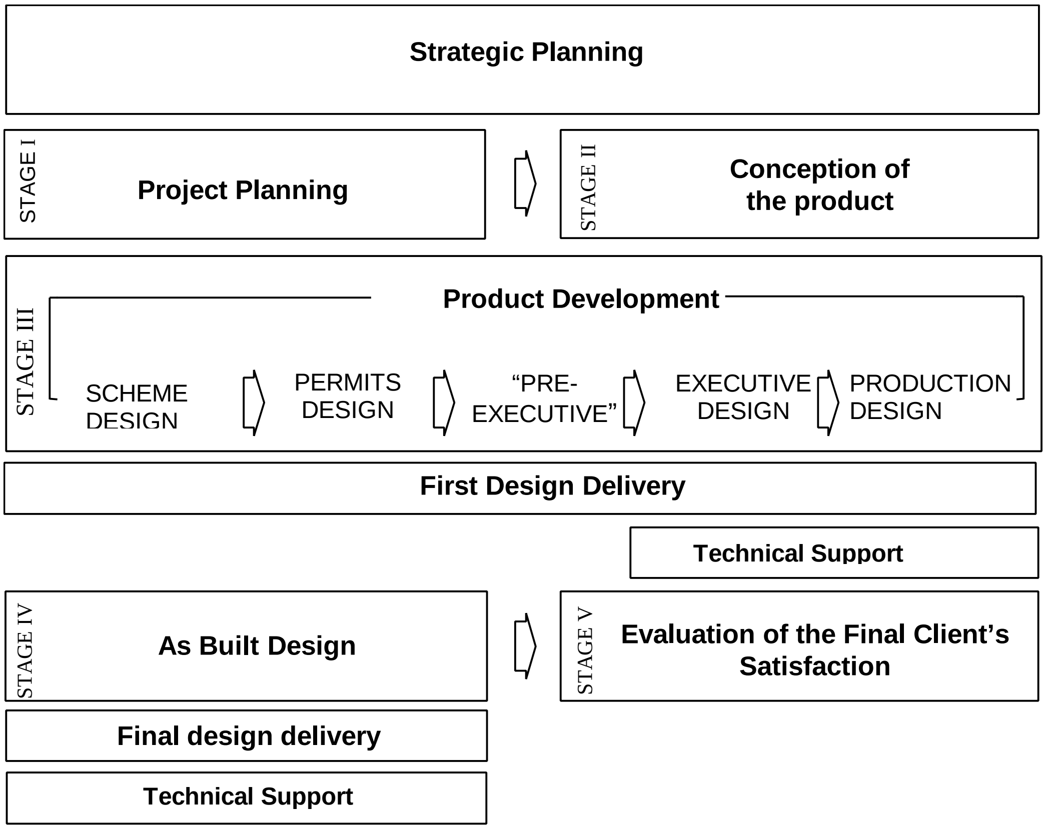


Figure 2: Stage Flow of Design Development

While analyzing the process macro flow, presented by Figure 3 and the CET (1998) detailed flow, one can clearly observe a conversion process of information and requirements into design specifications and details.

The Management Process participants efforts studied also include process flow efficiency concerns, in order to (i) establish, previously, the necessary inputs and information to a new design activity beginning and (ii) to plan the process to minimize waits and eliminate rework.

The design and conception process, however, is rather complex and includes, as notes Austin et al. (1994), sequentially dependent activities, cared in parallel independent activities and, also, multiple activities that should be cared interdependently and demand a different professionals interactive and linked action. As note Formoso et al. (1998) and Tzotzopoulos (1999), the design process interactive nature is alternatives generation and choice inherent and is fundamental to developed solution quality. Therefore, it should be emphasized and can't be mixed with mistakes and poor process planning rework.

It is exactly the low interactivity and the poor articulation between involved agents that, in the case studied, is responsible for the process improvement impediment. This low interactivity origin is, mainly: (i) contracts conflicts and agents relationship difficulties and (ii) the design activities low integrated sequential action.

Two actions are potentially important to this picture transformation:

- Partnerships that solve in advance contract problems and create ways to promote design and production process agents synergy;
- Design process orientated by simultaneous engineering practices that privilege the interactivity - as will be discussed in bellow item.

CONCURRENT ENGINEERING AND THE BUILDING CONSTRUCTIONS

IDA (1988) defined Concurrent Engineering (CE) as a systematic approach to integrated concurrent product designs and their processes. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements.

The fundaments for new product development through CE, according to several authors, as Hall (1991), Carter and Baker (1992), Hartley (1992), Love and Gunasekaran (1997) among others, are:

Simultaneous product development process stages execution. Specially, product and production designs integrated development;

Design integration of production process different agent's approaches. This is expected to occur by multidisciplinary team implementation that considers, while elaborating the design, the product life cycle. A multidisciplinary team provides incentive for interaction, emphasizing design coordinator role;

Strong client and user satisfaction orientation (transformation of client desires into design specification), eliminating activities that don't add value to the product.

Manufacture concurrent engineering application has lead to expressive time reduction and new and creative products market release. This is made possible by product development activity parallelism and, also, has eliminated several design originated production and use problems, by product life cycle several agents bigger and earlier integration.

As Tahon notes (1997) manufactures and building industry evolution factors are, worldwide, the same: (i) productive increase, (ii) time spent for products disposition and conception decrease, (iii) product quality improvement, and (iv) cost reduction.

Therefore, according to Tahon, construction CE application goals are similar to the ones in manufacture, as a whole.

However, the CE engineering two main goals (design and new projects release time reduction and building life cycle design consideration), in Brazilian construction, should be seen vis-à-vis the sector reality and its development necessities.

It is frequent in Brazil design development time to be very short. This is archived, most of the time, by not very mature designs, with very little details. This makes bigger design time reduction hard to consider, even when parallel activities are executed. In on hand, it is likely that CE broader practices end up meaning some design time and demanded effort increase. On the hand, however, it may generate lesser mistakes and specialties unfeasibility and easier to built designs. This may mean very important building execution time gains.

A delicate point associated to CE is the products new concepts proposition. This capacity should be carefully approached, once the markets are consolidated and present a product traditional image very related to clients, which are, in their majority, afraid of radical innovations. On the other hand, the capacity to develop and suggest building construction technologies innovation that respect client desire, may contribute to firms competition, once the traditional construction process is characterized by several inefficiencies and problem that influence construction cost and product quality. The goal "to actually integrate the several project aspects early", optimizing product life cycle in the design, turns it a priority to the construction, considering the traditional waist, pathologies etc. Most of this could be avoid with an early connection between involved agents with more expressive product development.

Therefore, construction new products development CE application may mean an important strategy to solve several deficiencies during project life cycle. (Love and Gunasekaran 1997). Table 1 presents several construction problems that may be CE approached.

Table 1: Improving Construction Efficiency by Concurrent Engineering Strategy (Love and Gunasekaran 1997)

Criteria	Construction Issues	Concurrent Engineering Strategy
Quality	Clients' and end user requirements	Systematic consideration of clients and end user requirements
Information flow	Interaction between participants	Team-building, proactive management, collaborative decision making
Efficiency	In-depth constructability analysis	Focus on the design and development phase
Project completion time and cost	Subcontractors, major subcontractors, rework and errors, inflexible procurement systems	Quality design and documentation, involvement of subcontractors and major contractors during the early stage of the design phase, CIM, robots
Major cultural, behavioral, organizational, behavioral issues	Clients' and end user participants for co-operative supported work	Leadership, motivation, incentives, training, multimedia
Design optimization	Non-value adding actives, delay in the project completion	Design for constructability, design for quality
Elimination of non-value adding activities	Physical movement of resources, information exchange and hand over between subcontractors	JIT, life cycle design for construction, activity-based analysis

Despite its potential, construction CE application should be approached considering the sector characteristics that present several differences (partially listed on Table 2) from the industry, as whole.

Therefore, in order to implement construction CE practices, it is necessary to define models and methods that may answer to specific sector problems (Tahon 1997). Deep transformations, that include (i) firms and project organization, (ii) participants culture, (iii) new technology that support information and project must be introduced.

Table 2: Construction peculiarities that may interfere on CE application

Construction project nature:	(i) Project planning and programming, (ii) conception and design (iii) and production are much more spread in construction.
Culture and related aspects:	Between agents relations are much more temporary and contractual, not repetitive project cycle oriented; Differently from manufacture, as a whole, the clients generally interfere significantly on project internal management.
Suppliers:	For several market and geographic reasons, same supplies maintenance, to different projects, is very difficulty; Considering firms involved different sizes, the negotiation power, concerning to suppliers is more limited.
Production scale:	Construction usually works with small scales. This relatively decreases the product cost amortization possibility.
Construction site limitations:	The production place (site) is more vulnerable to variations and climate phenomena in construction.

Concerning to organizational structure, CE requires a constant and broad interaction between the agents, in order to integrate people in multidisciplinary teams, with formal and interactive communication process, which the coordination may guarantee pertinent information distribution between design team participants. Design multidisciplinary teams constitution in the Construction sector is complicated by process fragmentation due to several agents of different firms

Therefore, in order to create transversal structures that guarantee process interactivity, different project participants firm deep cultural changes are necessary. These include the interactive flow approach oriented design teams establishment.

The magnitude of organizational and cultural change required points out to concept importance and partnership practice, as necessary tools to solve conflict and create a synergy between production process agents.

In order to, technologically, make possible this design collective environment implementation, characterized by several different people responsibility distribution, from different firms, geographically separated, it is necessary computer practices and telecommunication generic use, as a new collaborative design aid support.

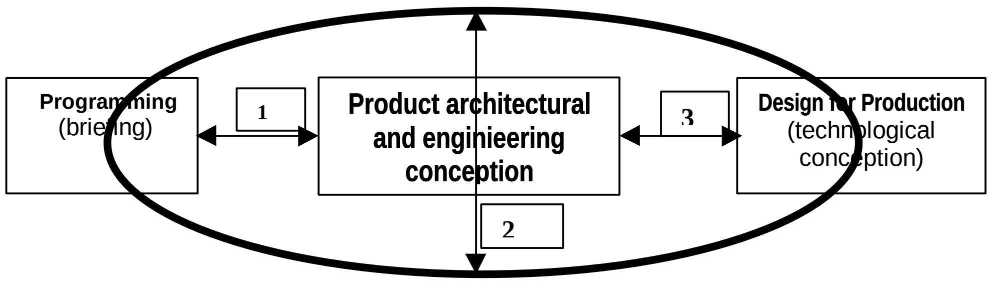
In face of these CE application sector difficulties, it is wise, in a first moment, to concentrate efforts increasing design process interactivity. Regarding this, Jouini (1999) points out three major collaboration areas between simultaneous project agents (Figure 3.)

In order to archive this collaboration, the design flow should be rearranged, in such a way that allows and incentives the interactivity between design areas and specialists - as discussed in the following item.

RE-ORDINATION OF DESIGN FLOWS ACCORDING TO CE PRINCIPLES PROPOSAL

In order to develop the building in an integrated and simultaneous way it is necessary to establish an activity sequence that allows the contents of different designs (concerning to different specialties), in the same level of maturity, to be treated and solved in parallel.

In a practical view, to re-ordinate design flows according to CE principles, it is necessary to understand the information priority of each design activity and to characterize all kinds of interactions among them. After that, flows could be changed in such way to privilege the concurrent realization of activities. However, this work does not intend to detail design flows that are related to the level of evolution of the design solutions in each stage of each design specialty.



1 - Between design team and promoter simultaneous collaboration focus
2 - Transversal simultaneous collaboration to the design team (simultaneous design) focus
3 - Simultaneous collaboration between product conception and technological production conception

Figure 3: Three Project Design Process Concomitant Engineering Application Areas (adopted from Jouini 1999 by Melhado 1999)

The parallel realization of design activity of different specialties tries to increase the quantity and the speed of exchanges among agents involved, trading the compatibility of concluded design data (leading to the practice of re-work and limiting global improve of the design) through the conception coordination and the development of design (Figure 4.)

Analyzing the composed matrix at Figure 3, that corresponds to stages II and III (conception and development of product) at Figure 2, we can identify the ordering of designs according to the specialties of the design and the maturity of the design, representing a shortening of sequence in the activities.

In the first stage, the stage of collection and presentation of basic information on characteristics of the land and occupation is concluded and the developer is responsible for it. In the second stage, the activities of production of necessities program to be answered at the product development and the preliminary study of architecture, that will develop the product concept, are included. Information and experiences of other specialties of design and production professionals must be considered, in order conceptually coordinate developer and architect approaches to the other specialties and to analyze the repercussion of considered alternatives in the preliminary studies, regarding technological and constructive possibilities.

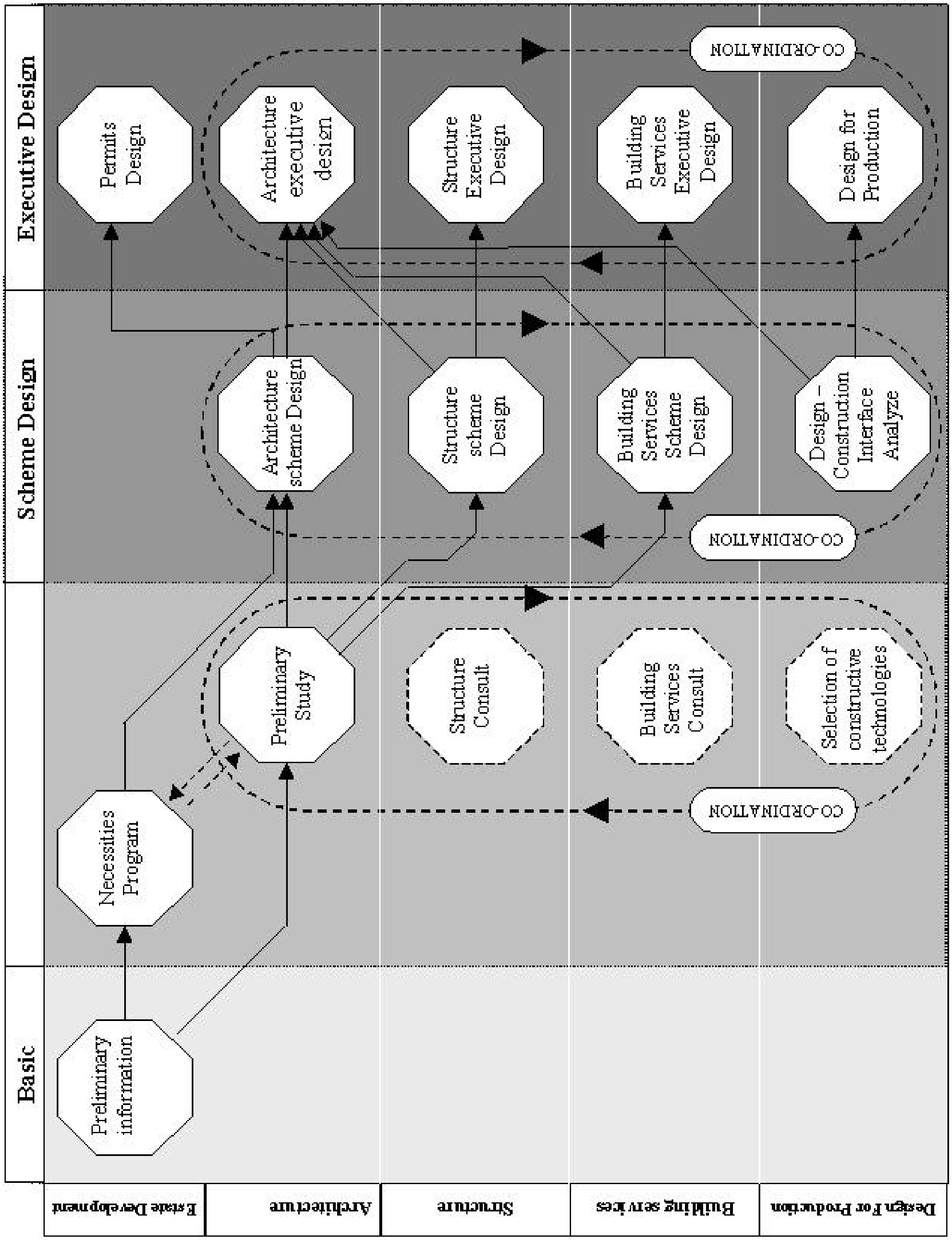


Figure 4: Proposal for Design Sequence Privileging Parallelism and Interactivity between Specialties

The third stage is related to the interactive development of the scheme design based on the several specialists approaches, in order to co-ordinate solutions of different specialties of design, seeking adjust specialty decisions and to improve the design as a whole. Finally, in the fourth stage, solutions of design specialties of the product, that subsidized the final definition of design to produce critical subsystems of the building process, are detailed.

CONCLUSIONS

The process of development of products in the construction of buildings presents a row of deficiencies that will rebound negatively in the quality of the products created and in its efficiency of building.

The poor performance of design, towards internal and external clients, is closed associated to the low interactivity between agents involved in the process of the design sector. As an alternative to this result, the use of concurrent engineering seems to be potentially promising in the search of oriented design processes to the completed development of several specialties, with significant repercussions in the design quality.

For the CE implementation, modifications in the design stages chain to privilege the parallelism among design stages and interactivity among design professionals are necessary.

Lean construction and Concurrent Engineering are yet distant practices and concept to the majority of Brazilian construction firms. The efficiency and quality improvement increase interest has, however, motivated the discussion and disposition to face such challenge.

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