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**A Research Framework for Operations Management in Large Scale Construction  
Projects.**

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**Abstract:** Large Scale Construction Projects (ETO systems) are inherently dynamic and complex, configured by networks operating as Virtual Enterprises. This way, coordinating the operational activities is a challenging task, due to the great number of aspects to be considered. This work shows a research framework developed for the Operations Management of these projects. The framework included collaboration aspects, representing an useful reference for decision making processes in these networked environments.

## **1. Introduction**

Construction is an activity of great importance for a country's economy, acting in the execution of residential and commercial buildings, infrastructure works and the diverse services related. Currently there are high investments in infrastructure works, especially in developing countries, the Large Scale Construction Projects.

Although it is a very traditional economic activity, it is known that construction is still seen as a low efficient sector. In the current construction practices, traditional project

management methods are still used, treating the works as a collection of small projects. The conflict between predetermined schedule and unpredictable reality results in significant wastes in the system (YU et al., 2009).

The enhancement of a works size and the uniqueness of each big project enhance the complexity for the management of operational aspects in construction. The construction systems can be classified as Make to Order (MTO), for the execution of pre-established projects, or Engineered to Order (ETO), for the execution of a work, including its conception (VOLLMANN et al., 2006). Large Scale Construction Projects are generally ETO systems.

This way, the operational management of the construction processes is a fundamental aspect for the efficiency enhancement desired by the sector. But, this knowledge area still does not have an integrated framework for concepts and practices. There is a great number of initiatives, tools and models found in the literature to support some aspects of the management processes in an independent way.

These findings were collected from a systematic literature review and are represented in an instantiated Concepts Model representing the State of the Art of Operations Management for Construction. It consists of the main background to reach the result desired.

The goal of this work is to develop a Research Framework for Operations Management in Large Scale Construction Projects. The Results and Discussion Section contains this Research Framework proposed. This framework can be considered an innovative approach for these fields – the Operations Management discipline in ETO systems and the Construction Sector. The innovative approach comes from the background of collaborative networks and Virtual Enterprises, refining, grouping and reorganizing the efforts found in the Literature Review.

## **2. Methodology**

An extensive Literature Review was conducted to establish the State of the Art of the Operations Management for Construction, the main basis for proposing the Research

Framework. The papers were collected from the main data bases of scientific papers (Web of Science, Emerald Insight and Science Direct), limited for the period between 2006 and 2010. The key words searched were “construction” and/or “management”.

The papers (one hundred and forty six) were then classified into six main knowledge areas, described in the Literature Review. This division permitted the discussion of the main subjects contained in each of them.

Then, it was possible to propose the Concepts Model related to the Operations Management for construction, using the EKD (Enterprise Knowledge Development) methodology (BUBENKO JR et al., 2001). This methodology is an integrated collection of methods, techniques and tools to support the analysis, planning, project and change processes of a business. It proposes six different models. The model used for this research was the concepts model – serves as a dictionary for understanding “things” and “phenomena”, being useful for the design of data bases (BUBENKO JR et al., 2001).

Then, the issues addressed are linked to the modern trends offered by Collaborative Networks literature, mainly Virtual Enterprises, guided by a recent, specific and descriptive literature review. It was possible to reflect about the existing gaps and propose an innovative Research Framework.

### **3. Concepts Model for Operations Management in Construction**

Operations Management focuses on the execution of a production system. As Vollmann et al. (2006, p. 83) delimitates, it represents “the mission that the production should realize to achieve the firms strategic goals”.

This way, Operations Management contemplates a series of decision areas. Some authors, as Pillkington and Meredith (2009), made some bibliometric analysis of the publications from this knowledge area, from 1980 to 2006, identifying the main subjects as: Manufacturing Strategy, Quality and its Metrics, Statistical Methods, Process Design,

Services, Qualitative Methods, Supply Chains, Product/Service Innovation, RBV (Resources Based View), Measures/Balanced Scorecard, and Inventory Control.

In a similar study, Taylor and Taylor (2009) found as the main topics for the Operations Management discussions, between 2004 and 2009: Supply Chain Management, Operations Strategy, Performance Management, Service Operations, Lean Methods, Resources Planning Systems, Quality Management and Product Development/Design.

Choudhari, Adil e Ananthakumar (2010) purposes in its research framework, six broad decision areas for production systems, that includes many of the subjects mentioned above: Production Planning and Control, Organizational structure and control, Human Resource, Facilities, Sourcing and Process Technology.

The majority of the classifications presented are generalizations and they cope mostly with traditional systems of manufacturing and services. Other studies discuss inter-firm relationships (BINDER; EDWARDS, 2010), the integration with lean competences (PARRY; MILLS; TURNER, 2010) and marketing (PAIVA, 2010).

Arditi and Polat (2010) mention the research areas found in academic programs of Construction Management: Contractual Management, Project Management, Scheduling, Resources Management, Construction Technology and Researches in Construction and Management.

However, none of the studies found establishes the areas related specific to the operational management of ETO systems, or specifically construction works. Therefore, we chose to delimitate the knowledge areas of the Operations Management for Construction based on the literature review made and on the adaptation of the areas proposed mainly from Arditi and Polat (2010) and Choudhari, Adil and Ananthakumar (2010). The areas are:

- Production Planning and Control;
- Resources Management – personnel, equipments and tools;
- Knowledge Management – innovation and competences;

- Supply Chain Management (SCM) – relations in the chain, materials sourcing and inventory control;
- Performance Measurement;
- Information and Communication Technology (ICT).

These six knowledge areas and the topics related found are briefly discussed in the next paragraphs, considering the synthesized Literature Review still encompassing traditional thinking for construction management.

There is a few identified studies on **Performance Measurement** for Construction Management. Most of them suggest Performance Indicators and Systems focused on the operational level, on the performance of a single enterprise, or on a single phase of the Construction Life Cycle (LÖNNGREN; ROSENKRANZ; KOLBE, 2010; NUDURUPATI; ARSHAD; TURNER, 2007).

Considering the area of **Planning and Control**, a previous work, using a systematic Literature Review, identified some techniques used to plan the operational activities in the construction sector (YANG, 2007). The most frequent practices were: simulation, delay analysis, critical path method (CPM) and resources levelling. All of these techniques are very well known, specially the CPM that has evolved through the time, with computational applications based on its principles (ABDALLAH et al., 2009; DUAN; LIAO, 2010).

The **Knowledge Management** practices identified are those linked to processes of Decisions Making (CHEN, 2008; SENARATNE; SEXTON, 2009), especially considering the business strategy (DAVE; KOSKELA, 2009). The main discussions are about the paper of the managerial function, the identification of the most valuable knowledge of the enterprise and the use of meetings as a way to exchange experience.

The **Resources Management** encompasses the transformation agents (personnel, financial support, materials and equipment). The discussions made about these four aspects are: the form to organize, train, make teams and manage people; the use of public-private

partnerships to provide financial support (big projects); the best way to select and manage materials and equipment (CHENG; TSAI; XIAO, 2006; GOLDENBERG, SHAPIRA, 2007; KE et al., 2009, STYHRE, 2006).

Construction **Supply Chain Management** is a hard task, due to its variable nature (SEGERSTEDT, OLOFSSON, 2010). Materials control, logistics and its fields, marketing, inventory, are the most discussed points of this section. Also, the application of lean principles (to the improvement of the production flow) and partnering relations between participants of the chain appear as new approaches to this knowledge area (KHALFAN; MCDERMOTT; SWAN, 2007; YU et al., 2009).

Although it is not possible to consider that **Information and Communication Technology** (ICT) is a traditional concept – especially when considering the construction industry – the majority of the applications identified are punctual solutions to the explored knowledge areas above. Most of the initiatives found present innovations and interesting intentions, but they still fail to provide complete solutions to the construction systems (SALEM; MOHANTY, 2008).

The six knowledge areas together with some other concepts related found in the literature are represented in the Concepts Model for Operations Management in Construction from Figure 1. Certainly there are a number of other concepts and also more existing interactions between them. It is assumed that the Model can have limitations as it is based in individual interpretation.

Briefly describing the Figure 1, the Concept 1 – Performance Measurement – is highly based on the systems design to support the activity and the Performance Indicators through specific dimensions related. From Concept 2 – Production Planning and Control – there is an intensive use of specific solutions, each having benefits but also limitations. Concept 3 – Knowledge Management – has the process of decision making and innovation/value creation as its main contribution, with strong link to Concept 4 – Resources Management – especially



Virtual Enterprise/Virtual Organizations (VEs/VOs) are types of Collaborative Networks formed by “highly dynamic organizations, that forms themselves according to the needs and opportunities of the market, as well as remaining operational as long as these opportunities persist” (CAMARINHA-MATOS; AFSARMANESH, 2003). A Virtual Enterprise is considered to be unified by its mission and distributed goals (GORANSON, 1999), with a limited time extension of operation that identifies one Construction Project as a VE. But, although they have the same *modus operandi*, the construction industry still does not effectively operate as a VE (REZGUI, 2007), considering the collaborative perspective.

There is a wish for new methods and models for the effective management and activities coordination of this construction VEs (KELLER et al., 2006). Some authors emphasize the difficulty of managing a construction network chain, due to this characteristic of being created for unique projects, and having a delimited Life Cycle (DAINTY; BRISCOE; MILLET, 2001). From the life cycle phases (creation, operation, evolution and dissolution), it is considered that the operations phase is the most important one and that the evolution phase occurs simultaneously (CAMARINHA-MATOS; AFSARMANESH, 2008).

The Operations Management for Construction represents the search for existing and then recently developed methods and models related to the activities taking place in the operation and evolution phases of VEs.

Considering **Performance Measurement**, the literature on Virtual Enterprises/Virtual Organizations assumes that these forms of collaboration bring advantages to its members. The development of performance indicators based on the benefit's network concept provide a tool to analyze the evolution of the collaboration processes as well as the performance of individual networked members (CAMARINHA-MATOS; ABREU, 2007).

For **Planning and Control**, Virtual Enterprises Management demands methods and models used for the coordination of project activities. An appropriated initiative is the proposal of architecture for dynamic cross-enterprise processes' planning, execution and

controlling (KELLER et al., 2006). Another approach systematically generates comprehensive project plans by cultivating and enacting the logic and intelligence of incremental and collaborative planning strategies (VERHEIJ; AUGENBROE, 2006).

A collaborative **Knowledge Management** may encompass many different initiatives: provide an effective way to share knowledge between the operations works at geographically dispersed depots (DAVE; KOSKELA, 2009), represent a way to achieve construction innovation (RUTTEN; DORÉE; HALMAN, 2009), and also improvement of communication and cohesion among members, using a dedicated knowledge base (REZGUI, 2007).

In the collaborative networks, personnel are the principal resource to be managed. So on, the **Resources Management** has many interactions with the knowledge management one, and the search for the most appropriated core competences allocation. The goal is to achieve a knowledge value creation culture where technology assets, human networks, social capital, intellectual capital, and change management are blended successfully (VORAKULPIPAT; REZGUI; HOPFE, 2010).

For the **Supply Chain Management** the most important aspect discussed is the trust among participants of the supply chain, between leaders and their teams (REZGUI, 2007) and also in the intra-organizational and inter-organizational dimensions (ZOU; ZHANG; WANG, 2007). Considering that the chain operates in a dynamic environment in which agents, tasks and materials in process are strongly related to each other (LANDESMAN; SCAZIERI, 1996), the Planning and Control domain for VEs considers also many of the SCM principles.

Truly, the **ICTs** are, with the knowledge management, considered to be the most discussed aspect when considering the collaborative environment. Many proposals, models, architectures are being developed to cope with de unique requirements of virtual enterprises, dynamic contexts (CAMARINHA-MATOS; AFSARMANESH, 2003, 2005, 2008; GORANSON, 1999; KELLER et al., 2006, SCHERER; SCHAPKE; KATRANUSCHKOV, 2010), trying also to consider the various aspects from the knowledge areas being discussed.

## **5. Results and Discussion**

Now considering the referenced works and the discussions about each knowledge area with the approach for collaboration networks, we describe and justify the synthesized research framework proposed, represented in Figure 2. The core points and relations were the basis for the development of the Research Framework for Operations Management in Large Scale Construction Projects.

Beginning with the Performance Measurement, it is stated that it should encompass the biggest number of enterprises as possible (for the individual and network levels), but also should be performed during all the project evolution, as suggested by Camarinha-Matos and Abreu (2007). It considers mainly the clients requirements, reflected in all approaches consulted, the business strategy and project goals.

The planning and control activity will be performed mostly in the individual level for demanding specific tools and ICT solutions, although considering an extended time consumption within the project's evolution. The Project Management referred by Keller et al. (2006) and Verheij and Augenbroe (2006) and consensual between other approaches is linked to the collaboration platforms in a way to ensure the connection between all the participants of the Network.

It is considered that Knowledge Management is the heading for Innovation as stated by Rutten, Dorée and Halman (2009), and Continuous Improvements reflecting the indication from Rezgui (2007). Although there is no direct link between Knowledge Management and Collaborative platforms, it is considered that this ICT support is indirectly related from its intermediary relation with the Supply Chain Management.

A topic of special attention is the core competences being managed through the perspectives of Knowledge and Resources, as pointed by Dave and Koskela (2009) and Vorakulpipat, Rezgui and Hopfe (2010). These core competences are supposed to give strong support to innovation and continuous improvement, and also should be arranged in a way to

permit trust and partnering for collaboration, having an extended influence among enterprises when compared to Resources and Knowledge Management.

So on, the Resources Management plays an important role for the provision of Finance and Assets, with Public-private partnerships being of special relevance when considering large scale projects (KE et al., 2009). The allocation of these financial and physical resources has strong relation with the performance measurement and the planning and control areas.

Supply Chain Management deals with less tangible questions when compared to traditional approaches. For these temporary oriented approach, the activities of main relevance are related not only to materials flow, but to the improvement of partnering relations in order to achieve lean principles and use of new technologies to cope with the managerial requirements of dynamic relations, as stated by Cheng, Tsai and Xiao (2006), Landesman and Scazieri (1996) and Yu et al. (2009).

The collaborative platforms, as a result from the approaches collected (KELLER et al., 2006; SCHERER; SCHAPKE; KATRANUSCHKOV, 2010), are the main support for different enterprises and the collaboration between them. This ICT feature should be used through all the operation/evolution phase, having special relevance for the activities of the Supply Chain Management, the Planning and Control and the Performance Measurement.

The framework from Figure 2 establishes that collaboration for construction networks should be achieved by a very integrated approach encompassing, among other related questions, the interplay of materials processes (construction site), information processes (contractor's ICT platform) and monitoring and controlling processes (client's ICT platform), as pointed by Scherer, Schapke and Katranuschkov (2010). It is also considered that the axes (Project Evolution and Different Enterprises) have correspondence, respectively, with the dimensions of "along life cycle phases" and "different actors", proposed by this previous work – with the third dimension of "different decision making levels", although not represented, being a consequence of an integrated approach.

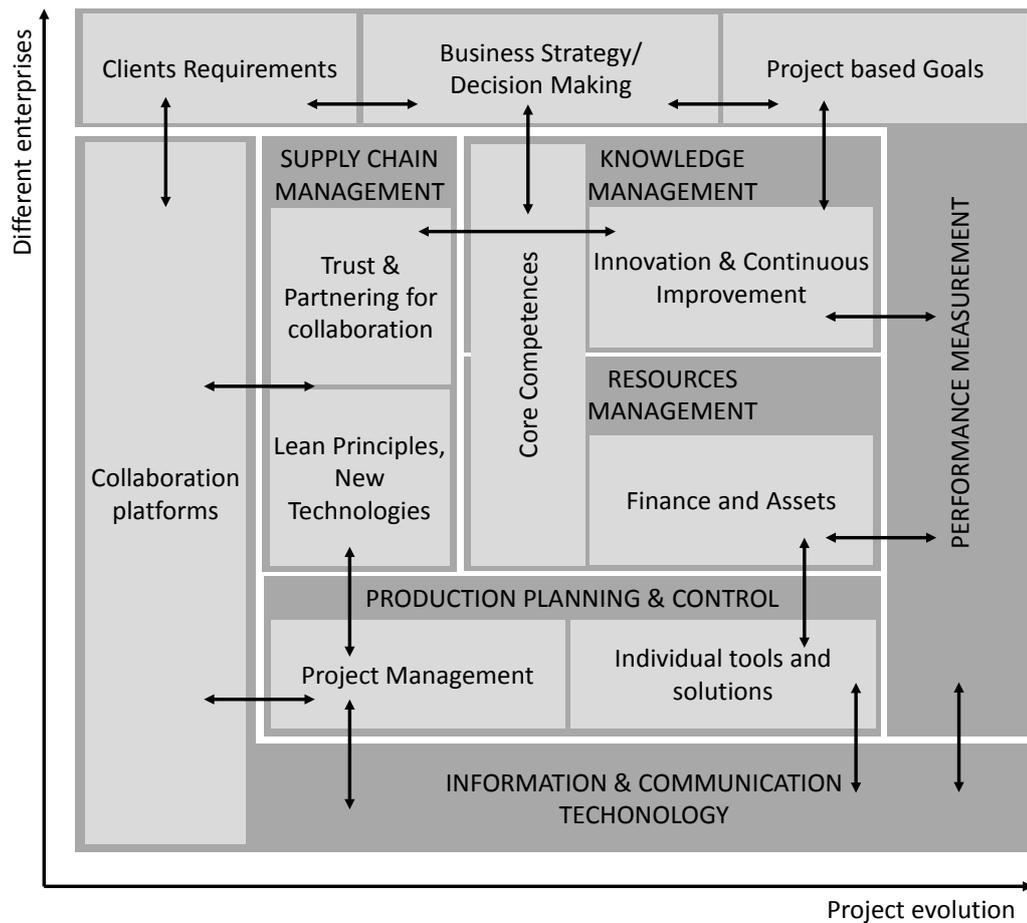


Figure 2: Research Framework for Operations Management in Large Scale Construction Projects

## 6. Conclusion

With the aim of develop a Research Framework for Operations Management in Large Scale Construction Projects, this paper started from a instantiated concepts model, after refined with specific literature review to design a systematic framework.

Although the framework developed can be seen as a generalization of the Concepts Model from Figure 1, it is considered to be an evolution from that – where a more integrated and lean approach is reached. Moreover, the dimensions of different enterprises and project evolution (the axes) for the operation/evolution phases are represented, trying to give some approximated notion about scope and scale of the activities in a collaborative network.

It is good to emphasize that, although most of the material found in the literature have some relation with the ICT area, its activities are relevant in order to support collaboration, not to be the main driver of it. Together with the Performance Measurement, these knowledge

areas fulfill the collaboration system with inputs and outputs relations necessary for the decision making processes and efficient management. Collaboration should be achieved by interdisciplinary and integrated activities of knowledge areas.

But, Operations Management for Constructions still deserves many academic and practice efforts in order to be a consistent subject for researchers and managers. This subject should be focused on the improvement of the quality of decision making to enhance the efficacy and efficiency of construction works and the (virtual) enterprises constituted for that. A great number of research topics can approach these questions.

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