Table 4.Weighs of Each Indicator.

Name	Weights	Name	Weights	Total Weights
Ownership	0.3399	OR	0.5858	0.1991
advantages		OA	0.4142	0.1408
International	0.2712	IO	0.4142	0.1123
advantages		IS	0.5858	0.1589
Diversification	0.2269	DP	0.4142	0.0904
		DR	0.5858	0.1329
Internationalization	0.1621	SR	0.4094	0.0664
speed		SA	0.2953	0.0479
		SC	0.2953	0.0479

Testing the framework with comparative case study. Comparative case studies of TCFs in China and Europe were conducted to test the framework and identify the shortcomings of internationalization strategies of Chinese TCFs in different aspects. Five Chinese TCFs were China Railway Construction Corp Ltd. (CRCC), China Railway Group Ltd. (CRG), China State Construction ENG'G Corp. (CSCE), China Communications Construction Group Ltd. (CCCG), and China Metallurgical Group Corp. (CMGC). Five European TCFs were Group ACS, Vinci, HOCHTIEF AG, BOUYGUES and SKANSKA AB. They were selected according to the total revenue rank of the Top 250 International Contractors (ENR 2013). Publicly available data of the selected TCFs were collected, including ENR top international contractors' list, annual reports, and research reports (see Table 5). All data was standardized to unify the units. Calculation formula of the final score of TCFs was shown below, w_i is the weight of each indicator.

$$\alpha = \mathrm{OR}w_1 + \mathrm{OA}w_2 + \mathrm{IO}w_3 + \mathrm{IS}w_4 + \mathrm{DP}w_5 + \mathrm{DR}w_6 + \mathrm{SR}w_7 + \mathrm{Sa}w_8 + \mathrm{SC}w_9 \quad (1)$$

Table 5.Practical Framework for Evaluating Internationalization of TCFs.

Indicators	OR (%)	OA (%)	IO	IS	DP	DR	SR (%)	SA (%)	SC (%)
CRCC	2.54	4.93	8	20	4	5	-16.39	35.66	-47.26
CRG	4.64	5.09	NA	7	3	6	11.95	38.12	-53.93
CSCE	6.13	2.46	8	17	6	6	1.59	60.25	-35.26
CCCG	23.64	3.27	57	29	6	6	25.50	-5.98	-26.85
CSCE	7.28	24.34	10	6	4	4	30.34	-7.11	-62.94
ACS	84.44	61.62	0	317	9	6	205.98	16.23	123.59
Vinci	36.59	8.77	0	90	7	6	5.71	12.85	-13.72
HOCHTIEF	94.82	24.21	48	41	9	4	12.33	5.98	4.42
BOUYGUES	41.89	19.11	0	172	7	5	7.01	-7.11	-26.72
SKANSKA	77.20	79.69	0	36	8	3	6.90	1.65	1.82

EVALUATION RESULTS

The evaluation results are shown in Figure 1. Totally, the five European TCFs have higher scores than Chinese ones. Most scores of Chinese TCFs are less than 0.5, while all these European TCFs' are higher than 0.5 (Group ACS even reaches 2). CCCG has the highest degree of internationalization among the five Chinese TCFs. CSCE, CRG and CRCC rank second, third and fourth, respectively. CSCE has the lowest internationalization degree among these firms. HOCHTIEF AG and SKANSKA AB comes after Group ACS. BOUYGUES and Vinci have similar internationalization degree, whose scores are among 0.65 to 0.70. There exists an obvious gap in internationalization degree between the European TCFs and the Chinese TCFs.

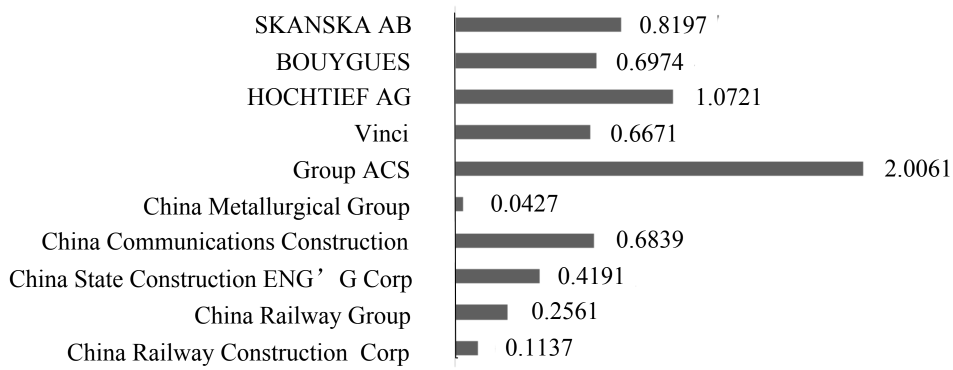

Figure 1.Evaluation results of case study firms.

Ownership advantages of Chinese TCFs are less than European TCFs. Although some Chinese TCFs have a high total revenue, the international revenue accounts for small proportion. Most percentages of the international revenue are less than 10% of the total revenue in Chinese TCFs, while the average percentage of European TCFs is more than 60%. Overseas markets are waiting to be utilized better for Chinese TCFs. These TCFs thus should focus on internationalization strategies to improve the internationalization degree.

Overseas subsidiaries and offices of Chinese TCFs are much fewer than the European TCFs'. Majority of these subsidiaries and representative offices are located in Africa, Asia, Middle East and Latin America, whilst few have been set up in European and Northern American markets. In contrast, the European TCFs have more access into the two markets and seek the largest market share. A more stable market network is waiting to be built for Chinese TCFs. This goal can be achieved by setting up more subsidiaries or representative offices, and entering by Joint-venture or other models.

Comparing with the European TCFs, Chines TCFs perform not well in diversification. Most of their projects limit to traditional building construction and municipal engineering. General construction contract is most frequently adopted, regardless their low technical demands and a little additional value. In contrast, the TCFs in Europe have wider business areas including petroleum, industrial process, power, water supply, manufacturing, sewerage or solid waste, hazardous waste and telecommunications. Chinese TCFs are advised to expand their business areas according to their strategic direction and technical and managerial strengths to get more opportunities in international construction markets.

Internationalization speed has the least weight among the four dimensions.

However, it reflects the evolving nature of the internationalization process of these TCFs. Internationalization pace of European TCFs is much steadier. Most Chinese TCFs shows an obvious increasing trend, either. These European TCFs positively promote the merger and acquisition strategies. The alliance between giants has complementary advantages and largely improves the competitiveness. Especially, when they enter international market, establishing alliance with local companies would increase the likelihood to gain success. Besides, the internationalization process is also pushed by a concession system through various public-private partnership contractual models. Much more strategies of internationalization should be recognized and developed for Chinese TCFs.

LIMITATIONS AND CONCLUSIONS

Overall, establishing an evaluation framework of the internationalization degree of TCFs in China is urgently needed, where many companies are striving to survive and compete with their strong and experienced counterparts from developed countries. The evaluation framework here has practical value for those firms in the international construction market. Combining with the comparative study which described the gaps between Chinese TCFs and European TCFs, this research also finds out shortcomings of Chinese TCFs in different aspects, e.g. insufficient international market share, weak diversification, lack of entering mode etc. These weaknesses are common for most TCFs in China because they compete at a similar level with the similar size, organizational capabilities, and constraints on international development and expansion. Advantages and sound internationalization strategies of the European TCFs, meanwhile, provide good instructions for Chinese TCFs.

Of the research limitations, first, the indicator selection is limited to the availability of the data. In order to reserve the basic indicators without sufficient data, data of international non-current assets was adopted because of unavailability of international current assets in the annual reports of Chinese TCFs. The second limitation is that the evaluation of qualitative measures requires considerable time and effort and may have a direct impact on the accuracy evaluation results. Finally, the applicability of the framework may be limited by the fact that internationalization degree measurement practices adopted by Chinese state-owned enterprises which may be different from those of other private or public companies in Western countries because institutional and cultural factors could have an impact on the development of their PMSs (Fleming et al. 2009; Li and Tang 2009).

The principal contribution of this paper is that a practical evaluation framework is designed to evaluate the internationalization degree of TCFs. This extends the knowledge of internationalization of construction firms and enriches the literature on internationalization degree in construction industry, where more research is still needed.

REFERENCES

Dunning, J.H. (1980). "Toward an eclectic theory of international production: some empirical tests." *Journal of International Business Studies*, 11(1), 9-31.

Dunning, J.H. (2000). "The eclectic paradigm as an envelope for economic and business theories of MNE activity." *International Business Review*, 9(2), 163-190.

Engineering News Record (ENR). (2011). *The top 225 international contractors*, McGraw-Hill, New York, 53-57.

Engineering News Record (ENR). (2012). *The top 225 international contractors*, McGraw-Hill, New York, 8-9.

Engineering News Record (ENR). (2013). *The top 250 international contractors*, McGraw-Hill, New York, 15.

Fleming, D.M., Chow, C.W. and Chen, G. (2009). "Strategy, performance - measurement systems, and performance: A study of Chinese firms." *Int. J. Account.*, 44(3), 256-278.

Forman, E.H. and Gass, S.I. (2001). "The analytic hierarchy process - An exposition." *Operations Research*, 49(4), 469-486.

Jin, Z., Deng, F., Li, H. and Skitmore, M. (2013). "Practical framework for measuring performance of international construction firms." *Journal of Construction Engineering and Management*, 139(9), 1154-1167.

Li, P., and Tang, G. (2009). "Performance measurement design within its organisational context: Evidence from China." *Manage. Account. Res.*, 20(3), 193-207.

Low, S.P. and Jiang, H. (2004). "Estimation of international construction performance: analysis at the country level." *Construction Management and Economics*, 22(3), 277-289.

Pheng, L. S., & Hongbin, J. (2004). Estimation of international construction performance: analysis at the country level. *Construction Management and Economics*, 22(3), 277-289.

Pheng, L.S., Jiang, H. and Leong, C.H. (2004). "A comparative study of top British and Chinese international contractors in the global market." *Construction Management & Economics*, 22(7), 717-731.

Sui Pheng, L. and Hongbin, J. (2003). "Internationalization of Chinese construction enterprises." *Journal of Construction Engineering and Management*, 129(6), 589-598.

Leaning by Experience: A Game Approach to Teaching Construction Scheduling

Søren LINDHARD[1]

[1]Assistant Professor, Department of Mechanical and Manufacturing Engineering, Aalborg University, Aalborg, Denmark, Email: lindhard@m-tech.aau.dk

ABSTRACT

To introduce students to the complexity of on-site management a game-approach has been developed for teaching purposes to simulate the production control challenges site management is phasing. The simulation model have been both alpha and beta tested to ensure the validity of the model. The simulation model takes its outset in 9 on-site constraints which is used to identify key requirements of the simulation model. The game consists of three phases a scheduling phase, a construction phase and a follow up phase. During the scheduling phase it is decided what needs to be completed in the next construction "window" and the necessary resources are ordered. In the construction phase the actual output is determined. Finally, in the follow up phase time usage and PPC is calculated and the schedule is updated. The feedback from the game session was positive where the game was found to be both amusing, engaging and an instructive experience at the same time.

INTRODUCTION

On-site construction is characterized as a unique (Salem et al. 2006), complex (Bertelsen 2003a; Dubois and Gadde 2002), and labor depended process. Constructions are fixed in position; thus, the craftsmen move through production instead of the product (Ballard 2000; Ballard 1998; Schmenner 1993). This creates a dynamic construction process where work areas move and material and crews vary; thus, all is based on the demands from the current activities completed on-site (Choo and Tommelein 1999). Moreover, completion is complicated by the limited space, the multiple components, the many interdependencies, and a general lack of standardization which dominates on-site construction (Ahmad and An 2008; Bertelsen and Koskela 2004; Bertelsen 2003b; Ballard and Howell 1995).

The practice of time management has to be learned by experience; therefore, to create an opportunity for learning to students on the construction management program a practical simulation model is developed and applied as a teaching instrument. To create a realistic experience, the simulation needs to incorporate the characteristics of on-site production. The importance of simulation as a teaching technique is underlined by Lateef (2010) which point out that it can be used as a platform to create knowledge, skills, and attitudes which have to be learned in practice. Long et al. (2009) elaborates by stating that some aspects of engineering are requiring experiences to gain a fully understanding and that this could be achieved by applying simulation into teaching.

METHODS

In order to make a realistic simulation of on-site production a crucial task is to identify and define the requirements to the simulation model. The key requirements to the simulation model are based on the constraint model presented in Lindhard and Wandahl (2012). The model divides the constraints into nine main categories and is an expansion of Bertelsen preconditions (2003). The nine categories are described in the introduction section and are as follows: Known surroundings; Construction design and management; Connecting works; Workforce; Materials; Machinery; Working Conditions; Climate; Safety.

Based on the identified requirements, derived from the nine constraints, a simulation approach is developed. In this process complexity is reduced by keeping the simulation as simple as possible while still keeping it as close to real on-site construction as possible.

To ensure the trustworthiness of the simulation, the simulation model has been reviewed and discussed with peers (Lincoln and Guba 1985). Moreover, both alpha and beta testing of the simulation model has been carried out.

Introducing constraints and requirements. The goal is to create a simulation model which reflects real construction projects. Based on the key constraints, the requirements to the simulation model are identified. The requirements are listed in Table 1.

Table 1.Identified Requirements to the Simulation Model: *Importance is Categorized Into Low, Medium or High Based on an Immediate Estimation.

Constraint	Requirements	Importance*	Included	
			Yes	No
Known surroundings	The surroundings need to be known.	Low		√
Construction design and management	Task specifications and drawings needs to be present	High	√	
	Changes in design are possible.	Medium		√
Connecting works	Previous activities needs to be completed	High	√	
	Interrelationship between activities	High	√	
Workforce	Workforce needs to be present	High	√	
	The workforce move through the production instead of the product	Medium		√
	Different contractors are responsible for different tasks	High	√	

Table 1.(Continued).

Constraint	Requirements	Importance*	Included	
			Yes	No
Material	Materials need to be present.	High	√	
	Multiple of different materials exists	High	√	
	Materials are depleted	High	√	
	Deliveries and storage of materials are restricted	Low	√	
Machinery	Machinery needs to be present	High	√	
	Machinery is necessary to complete certain tasks	High	√	
	Different tasks requires different machinery	Low	√	
	Only one contractor can utilize the machinery at the time.	Low	√	
	Restrictions of rental time and delivery time	Low	√	
Working conditions	Satisfying working conditions needs to be present	High		√
	Activities restricted by space	High	√	
Climate	External climate can influence the production	High	√	
	Climate precautions can be installed to minimize the effect.	Medium		√
Safety	A safe working environment needs to be present	High		√
	Safety issues can stop the production	High	√	
	Safety can be improved by incorporating safety precautions.	Medium		√
Variation	Variation is introduced in the model to make the schedule unreliable.	High	√	

Introducing variation. A real life construction project is dominated by variations, making the project difficult to manage and to schedule. Therefore, to assist the constraints, variation is emerging in the simulation and thus imitating a real life construction process by being unpredictable and complex. Variation is included by introducing events during the simulation, these events covers both positive and negative variation. At every work day a productivity and an event card is drawn. The productivity card is stating the individual contractor's actual productivity while the event card is presenting an unexpected event or scenarios such as illness in the work force, breakdown in machinery, changes in deliveries, dwelling materials, and climate and safety hazards.

THE DESIGN OF THE GAME

In the following the game rules is presented. The presentation is constructed around the nine constraints mentioned above: Known surroundings; Construction design and management; Connecting works; Workforce; Materials, Machinery; Working Conditions; Climate and Safety, an in-depth description can be found in Lindhard (2014).

Known surroundings (Geometric restrictions). The outer edge which is shared by the foundation and the exterior walls, the horizontal division and the exterior walls, and the roof and the exterior walls is considered as a part of the exterior walls.

The edge shared by the foundation and the interior walls, the horizontal division and the interior walls, and the roof and the interior walls is respectively considered as a part of the foundation, the horizontal division, and the roof.

Construction design and management. The model consists of triangles in four different colors. The triangles are made of GEOMAG bars and panels which are connected by means of magnetism. The students are handed out drawings of the constructions facades and sectional views. A 3d drawing of the construction can be viewed at Figure 1. A contractor daily production is a normal distribution with a mean value at 2.5 and a can take the values (0, 1, 2, 3, 4, 5) with the possibility of a production boost, introduced by the event card.

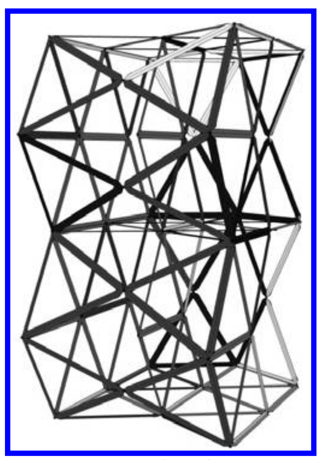

Figure 1.The model which is to be constructed.

Connecting works. The construction is constructed as a "real-life" building (Figure 1); thus, the physical relationship between activities creates restriction which is ensuring that previous activities has to be completed before the successive activities can progress (Echeverry et al. 1991). Based on the physical restriction, the overall sequence is drawn, see Figure 2.

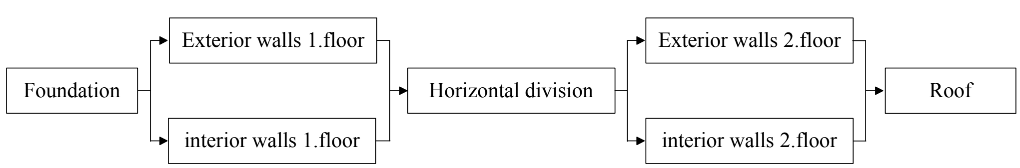

Figure 2.Interrelationships between activities.

Only the exterior and interior walls may be completed concurrent and in relation to "normal" physical restrictions. In any other cases a "section" (e.g. foundation, exterior walls 1st floor, horizontal division, etc.) of the building needs to be completed before the successive can begin.

Workforce. In the simulation the work is, as in real life, driven by the present labor. In the simulation four contractors is completing a specific task. Each contractor is responsible for one color, e.g. either: red, green, yellow or blue, and is restricted by the other contractors work on-site. Thus, only construction on the building is allowed. A contractor has to be booked 1 day before he arrives on site. One exception exists, a workforce can be present at simulation start; thus, the travel time is considered to take place before simulation start.

Materials. In order to complete a work activity the correct material needs to be present. To simplify the simulation every contractor only has only one type of materials: bars. As in real life materials are depleted during the construction, and new materials are needed. At maximum 15 pieces of materials can be delivered simultaneously; the next delivery can take place next work day. The delivery time to all materials is 3 work days. One exception exist, materials can be delivered at site when the simulation starts; thus, the delivery time is considered to be before simulation start. Materials delivered to site are stored and used when needed. The maximum storage capacity is 20 pieces of material.

Machinery. Certain work activities require machinery to be present. The tasks include foundation, exterior walls above the 1st floor, and roofing. The required machinery is depending on the work activity; thus, the foundation, the exterior walls 2nd floor south, the exterior walls 2nd floor vest, the exterior walls 2nd floor east, exterior walls 2nd floor north, and roofing all require different machinery. Moreover, only one contractor can utilize given machinery at the time. Rental of machinery has to be considered in advance since the delivery time is 5 work days. One exception exist, machinery can be delivered at site when the simulation starts; thus, the delivery time is considered to be before simulation start.

Working conditions. Working conditions are affecting work pace as in real life. Space is in particular important and is further restricted. At maximum three contractors can work on the project simultaneously and only two contractors can work on each"section" (foundation, exterior walls xx, roof, horizontal division, interior walls xx).

Climate and safety. The external climate is together with safety important and both can influence the production. Hazards both climate and safety is introduced through the event card.

FEEDBACK AND DISCUSSION

The simulation model was developed in an attempt to put the students as close as possible to a real life situation. This helps the students in understanding the challenges, the reasoning, and behavior of a construction manager (Lateef 2010).

The simulation model was applied at the first semester of the master program, and the students had the following feedback: + Amusing; + Engaging; + Learning outcome great; + Knowledge about what can happen; + Importance of control; + Effect of variation; + Good with complexity; % Drawings need more work; % Clearer rules - especially regarding machinery.

In general the feedback was very positive, and as the teacher I could really see the commitment increase among the students, thus; the result very much confirm Lateef (2010) statement that simulation approaches can make theory and lecture material come alive and thereby enhance the learning output (Gaba et al. 1998).

The simulation did serve as an eye-opener to many of the students where the complexity and dilemmas a construction manager is phasing while scheduling were experienced. Especially the "destructive" effect of variation was an instructive experience but in general getting the hands on were helping the students to fully understand the problem. Lateef (2010) points out that while fully understanding an issue your flexibility will increase helping you to adapt and understand new situations.

According to Lateef (2010) simulations can be used for: a) Technical and functional expertise training; b) Problem-solving and decision-making skills, and c) Interpersonal and communications skills or team-based competencies. Off cause teaching method should be selected in relation to subject and simulation is not the best approach for each lecture. Moreover, it had been very time consuming to develop and set-up the simulation game.

CONCLUSION

A simulation model has been applied to teach scheduling dilemmas to master students at the construction management program. Using a simulation approach in teaching has proven very beneficial in relation to the learning outcome from the students. Therefore, the key output from this study is that, practical simulations shall be viewed as a well-functioning technique which can help in stimulating engagement and learning amongst students. The technique is especially useful while teaching concepts applied in practice, in this case scheduling.

REFERENCES

Ahmad, H.S. and An, M. (2008). "Knowledge management implementation in construction projects: A KM model for knowledge creation, collection and updating (KCCU)." *International Journal of Project Organization and Management,* 1(2), 133.

Ballard, G. (1998). "What kind of production is construction?" *Proceedings for the 6th annual conference of the International Group for Lean Construction*, Guaruja, Brazil, 1-9.

Ballard, G. (2000). *The Last Planner System of Production Control.* University of Birmingham, Birmingham, 25-39.