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# Session 1-A

## 3 September 2019

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## Paper 18

# Evaluating the Sustainability of Land Development Projects

Wen-Der Yu<sup>1</sup> Wei-Cheng Ho<sup>2</sup> Shao-Tsai Cheng<sup>3</sup> and Hsien-Kuan Chang<sup>4</sup>

## Abstract

Former construction project usually emphasizes more on the cost, schedule and quality objectives, while less on the environmental, economic and social sustainability. The sustainability of non-urban land development project stands out from the others, not only because it covers a longer project lifecycle but also involves the change of natural planting, the protection of slope and the impact on the cultures of the local community. There has been not yet a sustainability evaluation system for non-urban land development projects. Without such an evaluation system, it is difficult for the planners to plan the sustainable project objectives, for the contractors to select the sustainable execution alternatives, and for the facility managers to operate sustainable constructed facilities. This paper proposes a Non-urban Project Sustainability Evaluation Indicator Framework (NPSEIF) via the reviews of legal and theoretical backgrounds from literature, focus group meetings, domain expert surveys, and case studies. Finally, a real-world non-urban land development project was selected to verify the applicability of the proposed NPSEIF. The result of this research provides not only a useful tool to the owners and participants of non-urban land development projects to evaluate the overall project sustainability, but also the right direction to improve the sustainability of land development projects.

**Keywords:** Non-urban land development, Sustainability assessment, Project life cycle, Project management, Performance indicators.

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## Paper 41

# Practices of Sustainable Development in Higher Education Institutions: Case Study of Al-Zaytoonah University of Jordan

Subhi M. Bazlamit<sup>1</sup>, Turki I. Al-Suleiman (Obaidat)<sup>2</sup> and Hesham S. Ahmad<sup>3</sup>

## Abstract

Al-Zaytoonah University of Jordan (ZUJ) has recently carried out a large scale sustainable energy project in an attempt to reduce its operational expenses. This comes as the university is seeking a sustainable campus in the areas of water, energy use and waste management. These projects have been completed in the last four years and their benefits are just being realized. This paper will take into detail these projects and cover their impact in terms of energy savings, environmental enhancement and the improvement of level of environment and security to the students and employees. An economic analysis of the feasibility and energy saving of the photovoltaic panels' farms that the university has installed is one example of the sustainable development. The university also adopted an irrigation system which utilizes reclaimed water from its wastewater treatment plant. The university also uses a network of dripping perforated pipes to water the vegetation on its campus. The education and awareness of sustainable development is also being disseminated among the students and faculty to create a partnership in sustainable development throughout the campus which include reduction in solid waste in terms of waste reduction, sorting and recycling. The university had also invested in energy efficient light fixtures, air conditioning and heating smart appliances. This paper will encompass the details of some practices of this sustainable development transformation. This research adopted a case study research method to present engineering projects applied in higher education institution, and to evaluate how these projects help to improve sustainable development and lean production management which will lead to reduction in cost and waste.

**Keywords:** sustainable development, energy, waste management, smart appliances.

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## Paper 44

# The Adoption of Building Environmental Performance Assessment Methods in the UAE Built Environment

Amna Shibeika<sup>1</sup>, Batoul Hittini<sup>2</sup> and Tasneem Abdel Raheem<sup>3</sup>

## Abstract

Current research in sustainable development of the built environment acknowledge the role of building environmental sustainability assessment methods as market changers for sustainable buildings' design and construction. While most of the existing studies are focused either on assessment methods, or on assessment methods' performance outcomes, this research addresses how assessment methods are adopted in practice. To address this, a pilot study was designed with desktop study of literature and regulation documents, as well as 7 guided in-depth interviews with 8 professionals engaged with assessment methods in the UAE. While, the spread of sustainable design and construction practices is motivated by mandating the assessment methods for all projects, but, with various rating requirements for government and private development projects, the analysis has revealed the continuous development of communication channels for the spread of sustainable design and construction practices between the regulative bodies with: a) clients through raising awareness activities, b) projects professionals through training and technical support, and c) suppliers of sustainable systems and products through quality assurance and certification procedures. Finally, the paper discusses these findings and outlines possible impact on theory, policy and practice.

**Keywords:** adoption, building assessment, sustainability, UAE.

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Paper 51

# **Sustainable performance in the earthworks sub sector: Exploring the machinery selection framework in New Zealand**

**Ryan Davenport<sup>1</sup> and James Olabode Rotimi<sup>2</sup>**

## **Abstract**

Sustainability is becoming more engrained in the culture of the New Zealand construction industry. More so when it portends social, environmental and financial benefits to organisations that are already operating under slim margins. This study explores means by which an appropriate machinery selection framework can be implemented in the earthworks sub-sector. Data was gathered through a qualitative analysis of the perspective views of six Project Managers involved in infrastructure delivery. The focus is on financial, environmental and social sustainability issues, and the potential impacts of machinery selection framework. Data obtained were analysed thematically, permitting an insight into key issues, challenges and success criteria for sustainable performance of organisations operating in the earthworks sub sector. The research findings could contribute to improved decision making in machinery use and increased efficiencies, which ultimately enhances organisations' social, financial and environmental ratings.

**Keywords:** earthworks, efficiency, machinery selection framework, sustainability.

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Paper 127

## Comparative Analysis of Methodologies for Calculating the Economic Life of Construction Equipment

Ilias Ladopoulos<sup>1</sup>, Kleopatra Petroutsatou<sup>2</sup> and Serafeim Polyzos<sup>3</sup>

### Abstract

The most profitable period of owning and operating a machine is during its economic life. To find the “sweet spot”, i.e. the time in the life cycle of the machine where owning and operating costs reach the minimum point, is a complicated task. It is evident that, in order to conclude with the best decision of either to keep or replace piece of equipment, repair-related cost information is indispensable, as it reflects machine’s DNA. Construction companies are currently facing an imbalance between the huge amount of owning and operating and maintenance (O&M) data that they have and the lack of solid organizational structures in order to make the best use of this knowledge. Thus, there is a dynamic that remains unused. This research highlights the advantages and disadvantages of methodologies for calculating the economic life of construction equipment and proposes a conceptual model that determines the replacement period using owning and O&M costs.

**Keywords:** Construction equipment, economic life, optimization methods, replacement, residual value.

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## Paper 140

## Costs and Benefits of Green Retrofits: A Case of Industrial Manufacturing Buildings in Sri Lanka

Achini Shanika Weerasinghe<sup>1</sup> and Thanuja Ramachandra<sup>2</sup>

### Abstract

Unless the rate of green retrofitting of conventional buildings is amplified, built environment will have a huge responsibility in dealing with global warming, reducing resource consumption and greenhouse gas emissions. The contradictory views on initial costs and paybacks have discouraged industries investing on green retrofits, and building owners are reluctant to pay for green retrofits. In this context, the current study analyses the costs and benefits of green retrofits in industrial manufacturing buildings in Sri Lanka towards identifying the most appropriate retrofit options.

The study used a mixed method approach to collect data through semi-structured interviews and documents of green certified industrial manufacturing buildings. Accordingly, four buildings were selected for the study, and the green retrofits applied in those buildings were identified through interviewing one professional from each building. Subsequently, the quantitative data on construction costs and economic savings were collected from two cases and analyzed using net present value and simple payback period. The analyses show that the use of green retrofits related to sustainable sites, water efficiency and material and resources are at a lower level, whereas green retrofits related to energy and indoor environmental quality are given the priority in existing industrial manufacturing buildings in Sri Lanka. Moreover, findings indicate the financial viability of the implemented retrofits in terms of sustainable features, such as energy and indoor environmental quality with positive net present values and simple payback period of less than 5 years. Considering the lifetime financial returns of those retrofits, each retrofit indicates significant benefits compared to initial investment. The outcome of the study would improve the application of green retrofits in existing buildings and thereby uplift the sustainable built environment by reducing greenhouse gas emissions and depletion of natural resources.

**Keywords:** costs and benefits, green retrofits, industrial manufacturing buildings, sustainable built environment, Sri Lanka.

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## Paper 99

# Minimizing Emissions and Cost through Reducing Equipment Idle Time in Concreting Operations

Nur Kamaliah Mustaffa<sup>1</sup> and Mohd Feisal Hafiz Abdul Aziz<sup>2</sup>

## Abstract

Concreting operations commonly utilize a large range of equipment that generates a considerable amount of greenhouse gas (GHG) emissions. Equipment idle time is considered as a non-productive time that it increases the fuel use and emissions without any production. Reducing idle time in operation implies the opportunity to improve productivity, cost efficiency, and emissions reduction. Continuous efforts have been made to determine the efficient solutions in reducing emissions of construction operations. Existing publications on concreting operations have focused on cost and production, with little attention being given to emissions. In response to this need, this paper aims to examine the influence of equipment idle times towards emissions, costs and production performance. This paper investigates the link between idle time, equipment utilization, production, emissions, costs, and optimum equipment configurations. Case study data along with Monte Carlo simulation are used to develop a model for cyclical concreting operations. The results highlight that eliminating most of the truck waiting time translates to higher utilization of both trucks and loader, thus increasing the non-idle fuel use and consequently increases emissions.

**Keywords:** Concreting operations, cost per production, emissions per production, idling time, non-idling time

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Paper 64

## Outcomes of Current Project Management Practices in South Africa

Godfrey Monyane<sup>1</sup>, Fidelis Emuze<sup>2</sup> Bankole Awuzie<sup>3</sup> Gerrit Crafford<sup>4</sup>

### Abstract

With the decline of the current economic conditions in South Africa, project performance is a great concern that needs attention. A qualitative case study strategy and semi-structured interviews were undertaken to determine the outcomes of current project management practices in South Africa. In terms of the performance of projects, the status quo paints a disconsolate picture. The poor performance continues to dominate the construction sector, especially in the public sector. Findings reveal protracted processes, and the use of unqualified and inexperienced contractors contribute to the poor performance of public sector projects. In addition, ineffective initiatives to curb the abuse of the procurement processes are directly affecting the outcomes of construction projects due to loopholes in the procurement process, and if this status quo remains, the sector will continue to have a bad image and continued waste of taxpayers' money will not cease until the public sector remove non-value adding activities in their operations.

**Keywords:** Project performance, Project management, Public sector projects, cost performance, time performance

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Paper 136

# The Effect of Perceived Safety on User Behaviour in the Holy Mosque

Kassim Gidado<sup>1</sup> and Mohammed Alkhadim

## Abstract

The Holy Mosque in Makkah is claimed to be the largest and most used crowded open space building in the world. It is used by very large crowd reaching maximum capacity of up to 2 million users at a time especially during the Hajj period. In practice, facilities managers of such buildings always give a lot of emphasis to objective safety (normative and substantive), but researches have shown that subjective safety (perceived) is equally important and cannot be overlooked. This research theorised that a decline in perceived safety (PS) will have an influence on user behaviour (UB) that could result in a crowd disaster.

Previous researchers have established that there are 10 key factors that could affect perceived safety in large space buildings, but no empirical study has yet been carried out to identify how significant is the effect of each of these factors on perceived safety and the consequent effect of perceived safety on user behaviour. This paper therefore presents the findings of an empirical study carried out by using the Holy Mosque as a case study.

Data was collected using iPad devices via a group-administered questionnaire to 1,940 pilgrims from 62 different nationalities during the Hajj period. The results were analysed using SPSS for descriptive analysis and AMOS 22 for Confirmatory Factor Analysis (CFA) and Structural Equation Modelling (SEM) to test the relationships between the factors and PS and between PS and UB by setting up a number of hypotheses. The findings revealed 7 out of the 10 factors have a significant influence on perceived safety and also established that perceived safety has a significant influence on the behaviour of the pilgrims as users.

**Keywords:** Subjective safety, Perceived safety, User behaviour, Large space buildings

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## Paper 60

**Safety Leadership Functions using Complexity Science****John Ojuola<sup>1</sup>, Sherif Mostafa<sup>2</sup> and Sherif Mohamed<sup>3</sup>****Abstract**

In other to put a proactive approach in place with regards to the prevention of workplace injuries, there is a lean towards the main determinants of safety; e.g. leadership. As a result of their vital role in organisations, leaders are seen as prime players in the creation of safe work environments. However, leadership is a complex, multi-phased concept which advocates that various leadership styles affect the outcome of safety in diverse ways. Therefore, this paper highlighted that complex systems predominantly focus on the relationship amongst teams, behavioural patterns and the interdependencies within an evolving system. Thus, applying the same concept to safety and leadership provided direction in practice and presented an unorthodox leadership construct that would enable managers to imbibe leadership apt for the twenty-first century. The aim of this paper was to develop a framework for safety leadership functions using complexity science. This study was centred on literature review based on the following themes – leadership style, complexity leadership theory and safety leadership. Discussions on the study carried out was presented, followed by a framework for safety leadership. This paper concluded that complexity science supports the flexibility, innovative and dynamism of leadership; not as a set of capabilities or standards innate in any one person.

**Keywords:** Complexity leadership theory, Leadership style, Safety leadership.

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## Paper 75

# Analysing the Resilience of Hospitals' Surge Procedures using the Functional Resonance Analysis Method

Farhad Mahmoudi<sup>1</sup>, Sherif Mohamed<sup>2</sup> and Fahim Tonmoy<sup>3</sup>

## Abstract

Hospitals are a critical element of the healthcare system and their continuous function is highly important to the wellbeing of communities. In accordance with the criticality of their functional performance during disruptive events, several modelling and analysis approaches have been developed to investigate the extent of various aspects of hospitals' vulnerability and resilience. However, these approaches fall short in addressing either the degree of absorption, adaptation and, in some cases, degradation of the hospital as a system before its fundamental breakdown or fail to differentiate their performance in normal conditions versus surge circumstances and protocols. In this paper, these issues were addressed via deployment of the Functional Resonance Analysis Method (FRAM) and a macro analysis of the interactions among hospital system functions under surge conditions. The use of FRAM as the modelling technique helps to address the extent of system adaptability to changes and explore the hidden impact of different functions on overall system performance. The modelling involved identification of surge functions and fulfilment of conditions for the functions generating the outcomes. The study identifies the limitations existing in hospital surge procedures and highlights the difference between work-as-imagined and work-as-done regarding hospital surge procedures.

**Keywords:** FRAM, hospital functional performance, resilience.

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## Paper 55

# Evaluating A Collaborative Cost Management Framework With Lean Construction Experts

Godfrey Monyane<sup>1</sup>, Fidelis Emuze<sup>2</sup> Bankole Awuzie<sup>3</sup> Gerrit Crafford<sup>4</sup>

## Abstract

The pervasiveness of in public sector projects running over budget is a call to all stakeholders to address cost performance issues in the construction industry. This paper proposes a framework for addressing construction cost performance issues that bedevil the public sector. The framework is intended to aid mitigation strategies required to overcome established cost management challenges. The framework was developed through the analysis of data from a qualitative case study research design. Projects and associated interviewees were purposively selected to ensure data alignment to the subject matter; cost management and lean construction. Projects experienced excessive cost overruns and there is a need for a more collaborative solution to managing costs. The data from the interviews were compared with the evidence from project-related documents to develop a framework that was validated through expert interviews conducted among lean construction experts. Excessive cost overruns were experienced from all case studies analysed. Thus indicating a continuous problem. Data support the need for a collaborative cost management framework to improve the performance of public sector projects. The collaborative practices and lean tools mentioned for improvement include the 5Whys, the big room, target value design, and the integration of design and construction. experts agree that the CCMF demand for professionals to really collaborate and hold them accountable for project delivery success.

**Keywords:** Construction, Cost, Collaborative costing, Cost Management, TVD

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# Session 1-B

## 3 September 2019

### 14:00-15:30

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	Bo Terje Kalsaas, Anders Rullestad, and Hanne Thorud
10	<b>Comparative evaluation of learning curve models for construction productivity analysis</b>
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## Paper 131

# Interactive Effects of Agile Response-to-Change and Project Complexity on Project Performance

Tuan Son Nguyen<sup>1</sup> and Sherif Mohamed<sup>2</sup>**Abstract**

Complexity is a critical factor in managing a project, as it presents an additional difficulty in achieving the project's objectives. As complexity makes a project more challenging to understand and keep under control, agile methodologies have been developed to enable increased flexibility and responsiveness to changing conditions. Therefore, it is essential to empirically examine the moderating effect of project complexity on the relationship between agile response-to-change (AR) and project performance. To address this objective, a questionnaire was used to measure project complexity, project performance and AR. Structural equation modelling was used to explore the relationship between these variables. The results suggested that internal AR has a positive effect on budget performance. Project complexity appears to lower the relationship between internal AR and schedule performance. As one would expect, the higher the level of project complexity, the more likely the project is to experience delays.

**Keywords:** Agile response-to-change, project complexity, project performance.

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## Paper 105

# Lessons Learned from Managing the Design Process of a Large and Complex Construction Project Seen in a Lean Construction Perspective

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## Abstract

The construction project being studied is a government investment related to a relocation of a biomedical institute delivering research-based knowledge and contingency support in the fields of animal health, fish health and food safety. The project covers a total of 63,000 square meters distributed over 10 buildings. The buildings have a very high degree of complexity due to a large proportion of special areas, great ambitions to the minimize environmental impact in addition to strict compliance to Infection Prevention and Control in order to achieve a world class product in its field. The project is procured as a design-bid-build project divided into 40 different execution contracts. The design alone has required 1 million hours and more than 100 000 000 Euro.

The purpose of this article is to study the applied methodology for managing the detailed design to identify lessons learned from the project. The theory underlying the study is inspired by lean design management and design theory linked to design as phenomena, including reciprocal interdependencies, iteration, decomposition, design as a “wicked problem”, learning, gradual maturation, etc. The article is based on an abductive research design and has been implemented as a case study where both qualitative and quantitative methods have been used.

First, the study describes how the design process was managed. Furthermore, challenges that are revealed through interviews and a survey are presented. Uncovered are a widespread volume of negative iterations and waste, where reasons for the challenges are linked, among others, to the use of traditional management methodology, a long user process and late owner and user decisions. Finally, the key lessons learned from the case are further explored in how they could be solved by alternative management methodology.

**Keywords:** AEC-industry, complexity, design, lesson learned

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## Paper 10

# Comparative Evaluation of Learning Curve Models for Construction Productivity Analysis

Panagiota Ralli<sup>1</sup>, Antonios Panas<sup>2</sup>, John-Paris Pantouvakis<sup>3</sup> and Dimitrios Karagiannakidis<sup>4</sup>

## Abstract

This paper investigates the role of learning curve models in estimating construction productivity. Learning curve theory is actively implemented for both the scheduling and cost estimation of complex construction projects. The purpose of the research is to assess the suitability of published learning curve models in effectively analyzing the learning phenomenon for substantially complex construction operations. The research investigates five (5) learning curve models, namely the (a) Straight-line or Wright, (b) Stanford "B", (c) Cubic, (d) Piecewise or Stepwise and (e) Exponential models. The methodology includes the comparative implementation of each one of the aforementioned models for the analysis of a large infrastructure project with the use of unit and cumulative productivity data. A two-stage investigative process for the five models was applied in order to define (a) the best-fit model for historical productivity data of completed construction activities and (b) the best predictor model of future performance. The assessment criterion for the suitability is the deviation of the real construction data from the predictions generated by each model. The research results indicate that the Cubic model dominates in terms of its predictive capability on historical data, while the Stanford "B" model is a better future performance predictor. Future research directions include the extension of the research scope with the inclusion of more learning curve models in conjunction with a populated database of historical field data.

**Keywords:** Construction productivity; Estimation; Learning Curves; Statistical analysis.

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## Paper 11

# Investigation of the Earned Value Method (EVM) Applicability for Construction Operations Affected by the Learning Phenomenon

Christos Stasinou<sup>1</sup>, Antonios Panas<sup>2</sup>, John-Paris Pantouvakis<sup>3</sup>, Panagiota Ralli<sup>4</sup> and  
Dimitrios Karagiannakidis<sup>5</sup>

## Abstract

The Earned Value Method (EVM) has been extensively applied for the analysis of construction projects. However, in cases where the productivity is not constant, but rather varies due to accelerations attributed to the learning phenomenon, it is challenging to assess the implications on productivity estimation and forecasting. In that sense, such an investigation is crucial for the scheduling and coordination of the remaining works in a realistic manner. The purpose of this paper is to compare the progress reporting results using the Earned Value method both for the theoretical project time schedule (without learning) and the actual on-site scheduling following the learning curve. A real, large-scale infrastructure project is used as a case study. The research method involved the “transformation” of productivity data to cost data, with the purpose of quantifying the productivity improvements through the use of statistical learning models. The straight-line model was used, due to its wide acceptance in related studies. An algorithmic approach is developed and assessed via, inter alia, the Schedule Variance (SV) and the Cost Variance (CV) indices. The results of the research indicate that EVM is significantly affected by the learning phenomenon, which, if neglected, leads to ineffective decision making procedures, regarding the deployment of project resources.

**Keywords:** Earned Value Method; Construction productivity; Estimation; Learning Curves.

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## Paper 73

# Using Analytic Hierarchy Process to Evaluate Implementation Barriers of Agile Project Management in Australian Project Environments

Jantanee Dumrak<sup>1</sup>, Sherif Mostafa<sup>2</sup> and Nick Hadjinicolaou<sup>3</sup>

## Abstract

In today's complex environments, projects are facing many challenges to being delivered successfully. Lacking appropriate change management, adaptation and transformation, disruptive technologies, competitive demand and supply, acquisition of scarce resources, and fluctuations of stakeholder and customer needs could become impediments in delivering successful projects. Agile project management (APM) is one of the project delivery approaches believed to be effective in creating responsiveness and efficiency for projects in achieving customer satisfaction, delivering high quality, productivity and project performance as well as accomplishing project goals. Nevertheless, the magnitude of non-traditional agile implementations in project environments can be at variations depending on methodology, sector and extent of agile practices. This research aims to identify and evaluate implementation barriers of APM in projects across different sectors in Australia. The Analytic Hierarchy Process (AHP) technique was employed to conduct the research analysis by organising and analysing the APM barriers across different industrial sectors in Australia. The research was designed into two consecutive stages. In the first stage, 15 barriers to agile implementation, as evaluation criteria, were identified and finalised by a panel of APM experts. The agreed barriers were organised into four categories of agile manifesto values. The second stage, 10 APM practitioners working in Australian projects were invited to analyse and rank the barriers to agile implementation. The results of AHP analysis include the pairwise assessment matrices of the studied categories and the overall rank of barriers to the APM implementation. The research findings aim not only at facilitating agile project practitioners to recognise the most important agile implementation barriers but also the contribution to the improvement of future APM implementation in Australian projects.

**Keyword:** APM, agile implementation, agile barriers, Australian project, AHP

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## Paper 74

# Investigating the Association between Project Portfolio Management Office Functions and Project Success: An Australian Case Study

Nick Hadjinicolaou<sup>1</sup>, Jantanee Dumrak<sup>2</sup> and Sherif Mostafa<sup>3</sup>

## Abstract

The functions of Project Portfolio Management Offices (PfMOs) support not only implementation of organizational strategic management and investment decisions but also ensure that organizational benefits are realized and successfully delivered by projects and programs. Nevertheless, the association between PfMO functions and project success remain under-researched. The aims of this research are to address PfMO functions commonly performed and review magnitude of the functions from Australian perspectives. Furthermore, the research significantly focuses on the association between PfMO functions and project success. The research data collection was conducted using questionnaire survey with 27 senior project and portfolio management professionals working in 6 Australian sectors. The relationships of 52 PfMO functions were cross-examined against 8 project success criteria using a statistical correlation analysis. The significance of PfMO functions in project success is highlighted. The correlation findings reveal diverse combinations of relationships between PfMO functions and project success in differing Australian sectors. Further discussion is provided for specific sectors to achieve higher performance of PfMO functions.

**Keywords:** project portfolio management, project portfolio management office, project success

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## Paper 130

**Feedback Loop – The Missing Link in Activity Analysis**Hasse H. Neve<sup>1</sup>, Søren Wandahl<sup>2</sup> and Jon Lerche<sup>3</sup>**Abstract**

Construction productivity has been stagnating and declining for decades. Thus, developing continuous improvement processes is crucial. The aim of this research has been to explore if the 3<sup>rd</sup> step “analyse” in the 5-step activity analysis continuous improvement process could be further developed to, in one workflow, set targets, identify improvement areas, unveil root causes and create motivation for change in an integral way fitting the existing five-step process. An exploratory single case study was used to collect data through the methods of activity sampling, semi structured interviews and observations. The research showed that a workflow called the Feedback Loop, involving craftsmen, foremen and an activity analysis analyst, could set targets, identify improvement areas, unveil root causes and create motivation for change. This was done by empowering craftsmen and foremen, in collaboration with the activity analysis analyst, to analyse the activity sample in a 7-step Feedback Loop fitting the existing 3<sup>rd</sup> step “analyse”. The implications of this research are that we could adjust the already well proven activity analysis continuous improvement process to improve future results. The conclusion is that the Feedback Loop worked in this project and trade, but further research is needed in other contexts.

**Keywords:** activity analysis, work sampling, continuous improvement, productivity, refurbishment

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## Paper 137

## Realization of Benefits from Best Value Approach by Proper Utilization of Expertise in Infrastructure Projects

Lashand Sivathasan Nadarajah<sup>1</sup>, Magnus Mikael Hellström<sup>2</sup>, Gøril Hannås<sup>3</sup>

### Abstract

In the search for improved contract and project management in construction, the Best Value Approach (BVA) is a concept that has been introduced with a proven track record for better performance. The BV-philosophy stresses the importance of proper utilization of vendor expertise, as well as reducing management, direction and control by assumed non-expert clients. The development of BVA has mainly taken place through lessons learned from a number of projects, and existing research is mostly concerned with practicalities and “how” to apply it. However, research is scarce on what characterizes an expert in a BV-context, and the concept lacks scientific documentation regarding underlying premises. To fill this void, we pose the following research question: How can vendor expertise be utilized in order to achieve BVA-benefits? We develop a framework for vendor expertise in BVA, and how it can be utilized to realize proposed BVA-benefits. The framework is based on both relevant theories and findings from an in-depth case study. Our contribution is an increased understanding of the expert-role in BVA, and how clients can facilitate for experts in BVA-projects. In this paper, we question the rationale behind BVA and discuss the underlying premises for transferring supreme responsibility of public construction projects to private marked vendors.

**Keywords:** best value approach, expertise, procurement, project management, uncertainty

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## Paper 139

# Adaptation of Risk Sharing Partnerships (RSP) to New Industries

Theodor Kvæven Halvorsen<sup>1</sup>, Gøril Hannås<sup>2</sup> and Magnus Mikael Hellström<sup>3</sup>

## Abstract

The aerospace industry has since the 1990s used a partnership model called Risk Sharing Partnerships (RSP) to handle certain challenges faced in the development of new aircrafts. The RSP model allows the client to include key suppliers in the development of a new product, and hence sharing the burden of investment, risk mitigation, as well as the future sales income. This makes it easier to acquire funding for the development of new products and technologies, in addition to accelerating the development process by including key competencies earlier (Buzacott, 2012). RSP have raised interest in other industries, which calls for increased knowledge of contingency factors of the RSP, as well as suppliers' perspective on RSP as a partnership model. Both are regarded important if cross-industry learning is to be promoted. By using a literature review of existing studies on RSP, combined with a case study of two aerospace suppliers, this study investigates the contingency factors of the RSP as a foundation for cross-industry transfer of knowledge, and proposes a model to assist cross-industry adaptation in project-based industries. We propose that there are three critical contingency dimensions for RSP-implementation, based on both financial and relational factors.

**Keywords:** Aerospace industry, partnerships, reward sharing, risk sharing, risk sharing partnerships

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## Paper 37

# A New Project Scheduling Control Method based on Activity Quantities

Hsien-Kuan Chang<sup>1</sup>, Wen-Der Yu<sup>2</sup> and Tao-Ming Cheng<sup>3</sup>

## Abstract

The traditional Earned Value Management (EVM) suffers many theoretical weaknesses. The improved Earned Schedule Method (ESM) and Earned Duration Management (EDM) still adopt the basis of Planned Value (PV) and Earned Value (EV) for evaluating the overall schedule performance. They tend to mislead the manager's conception of *de facto* schedule performance. To resolve the abovementioned problems of traditional schedule control methods, this paper proposes a new method, namely the Quantity-based Project Schedule Control Model (Q-PSCM), which adopts the concepts of EDM, but calculates the project schedule performance based on 'activity quantities' of the critical path instead of the overall 'activity values' in the traditional EVM. The quantity information is used to compute the project's 'Estimate to Complete (ETC)' duration using critical path method. The overall project schedule performance index is evaluated based on the information of current schedule, project ETC duration and project planned duration. The result of case study shows that the proposed Q-PSCM can evaluate the project schedule performance more effectively and provide a more useful and effective tool for schedule control of construction projects.

**Keywords:** Schedule control, Earned Value Management, Earned Schedule Method, Earned Duration Management, Quantity Survey.

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## Paper 46

# Application of Robotic Technology for the Advancement of Construction Industry in Sri Lanka: A Review

K.G.A.S.Waidyasekara<sup>1</sup>, Madhawa Gamlath<sup>2</sup> and Sonali Pandithawatta<sup>3</sup>

## Abstract

The construction industry is one of the least automated industries, and robot implementation at the construction site is limited. Moreover, the industry has traditionally not been a favorable area for the application of robotics. However, with the discovery of more cost-effective applications and motives such as reducing the labor force population, the aging of skilled workers, and safety issues, their use will undoubtedly increase, especially in the developed countries. Robotic technology provides many benefits for the advancement of the industry while the local construction industry is not fully geared to entirely implement such increased technological applications. Therefore, there is a need to investigate the feasibility of introducing robotic technology for the advancement of the construction industry in Sri Lanka as a developing country. Hence, this paper aims to review the importance and application of robotic technology to the local construction projects by critically studying the secondary data on global construction automation and to further discuss benefits and challenges. The paper also presents a view on the application of robotic technology in the Sri Lankan construction industry by reviewing secondary data and basing this upon the opinions from the preliminary survey.

**Keywords:** Application, Advancement, Construction, Robotics, Technology

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## Paper 52

# Integrating Lifecycle Thinking in Asset Management Through BIM: Opportunities for the Water Sector

E. Suprun<sup>1</sup>, R.A. Stewart<sup>2</sup>, S. Mostafa<sup>3</sup>, O. Sahin<sup>4</sup>, E. Bertone<sup>5</sup>

## Abstract

The water industry worldwide has been gradually transitioning towards digital asset management practices. Australia is no exception. However, these practices are often complicated by a lack of consistent models for gathering and maintaining up-to-date asset information across the industry. There is a need for innovative digital platforms and asset management solutions for making decisions that suit the increasing needs of the water sector. Building Information Modelling (BIM) can potentially be the conduit to asset management databases as it goes well beyond 3D models developed for use in the design and construction phase. The overarching goal of this research was to address the water industry challenge of implementing BIM to integrate digital data for the facility lifecycle as well as to provide information and decision support to asset management, and operation and maintenance. A number of workshops with asset managers and maintenance operators were held on the basis of a case study of a bulk water supply company in Australia. Stakeholders discussed specific expectations for the visualisation of information to ensure that data is used, understood and managed over the whole lifecycle. The barriers to the implementation of digital techniques for the purpose of efficient asset management were also explored.

**Keywords:** Asset information model, asset management, BIM, lifecycle thinking, water industry.

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Paper 54

# Information Systems Supporting the Optimization of the Prefabrication Process in the Construction Industry- Case Study of a Steel Plant

Krystyna Araszkiewicz<sup>1</sup>, Aleksander Szerner and Michal Wrochna

## Abstract

Dynamic changes in the macroeconomic environment of enterprises make it necessary to constantly improve production processes in order to maintain a competitive position. This article presents results of a case study on the implementation of digital tools to improve information management and production planning in a steel plant for construction purposes. Presented solutions will be an example of the possibility of using parametric models developed in accordance with the assumptions of the Building Information Modelling method in prefabrication. Tools for task planning and monitoring of material supply, transport to construction and assembly are described. A solution enabling planning changes is also presented, including automatic assignment of machines, employees, according to the importance of their tasks. The case study allows the identification of potential benefits, both organizational and economic, that result from the use of digital tools in the production of prefabricated steel structures. Application limitations, established on the basis of the case study, related to the use of digital solutions, are also indicated. On this basis, an attempt has been made to indicate the direction of further research in the field of digital prefabrication and its impact on the optimization of the production processes of construction companies.

**Keywords:** digitalization, prefabrication, construction sector, BIM

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## Paper 67

# Immersive Virtual Reality Environment for Construction Detailing Education using Building Information Modeling (BIM)

Maha ElGewely<sup>1</sup> and Wafaa Nadim<sup>2</sup>**Abstract**

Construction site visits are real-life practical experience where the AEC students' conceptual knowledge is developed and serves as an extension of in-class learning tools. Nevertheless, very low rates of construction site visits have been reported worldwide due to certain limitations, such as the limited visit time, the lack of visit objective, potential hazards, etc. In addition, site activities may also meet specific class needs. During a construction site visit, students mainly learn through their own observation, not by involvement in the site work or having the possibility to take decisions. Besides, students have only the chance to attend one phase of construction. Virtual reality (VR)—as a game - friendly, interactive, and immersive technology—may facilitate virtual construction site visits to meet learning needs and provide the learner with a near-real experiential learning environment where he/she can “learn by doing” in a zero-risk environment. In this essence, this paper describes “VRConDet” project which builds on the VR technology as a medium and Building Information Modeling (BIM) as a source of technical information taking into consideration adults' active learning and gamification of learning materials. “VRConDet” is a computer-assisted learning (CAL) conceptual framework for construction detailing that aims at enhancing the learning experience and learning outcomes for construction education within architecture curricula. This paper focuses on “VRConDet” system architecture and the design of its diverse, scalable, and adaptive modules according to the correspondent complexity and intended learning outcomes of construction education. The results of this first phase feed into a second phase of VR environment development and the validation thereof.

**Keywords:** building construction education, building information modeling (BIM), computer assisted learning (CAL), virtual construction site, virtual reality.

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## Paper 78

# The Support of Continuous Information Flow through Building Information Modeling (BIM)

Alireza Ahankoob<sup>1</sup>, Behzad Abbasnejad<sup>2</sup> and Peter SP Wong<sup>3</sup>

## Abstract

The lack of mechanisms to manage construction project information using traditional documentation methods leads to information waste. Building information modeling (BIM), as one of the recent developments in the architect, engineering, and construction industry (AEC) has revolutionized the process of managing information among project stakeholders. BIM is advocated as an effective platform that digitizes and accommodates all essential project information that can be extracted, networked and shared among project stakeholders to foster effective decision making and construction operations. Despite the significant role of BIM in supporting lean construction principles, there is little evidence on how BIM leverages continuous information flow in construction projects. This study aims to find the mechanisms through which BIM facilitates continuous information flow. A desktop study on secondary data was conducted to identify those mechanisms. The results of the secondary data analysis suggest that the key aspects of BIM in storing and transferring project information such as effective exchange of information, early involvement of project stakeholders, information accuracy and real-time access to project information can enhance information flow in construction projects.

**Keywords:** Building information modeling, construction projects, information flow, information waste.

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Paper 103

## Improving Formwork Design Using Lean Thinking

Chien-Ho Ko<sup>1</sup>

### Abstract

Formwork is one of major engineering works in reinforced concrete projects. Its performance affects project success and therefore profitability. Formwork engineering could be divided into design and construction phases. Conventional formwork engineering involves unnecessary non-value-adding activities, such as change orders and material movement. The objective of this study is to applying lean thinking in formwork design to reduce unnecessary waste, increase design reliability, and enhance construability. A lean thinking formwork design process is proposed to achieve the goal. Concurrent design and Building Information Modeling (BIM) ideas are used in the process to improve visibility. Design reliability is improved using design correctness reviewed by project stakeholders. Thus, a continuous learning culture is developed. A real building project is used to validate the feasibility of the proposed method. Analysis results demonstrate that the proposed approach could be used to increase design reliability and enhance construability, thus reduce unnecessary waste in formwork design.

**Keywords:** Formwork design, concurrent design, building information modeling, design correctness, system dynamics.

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## Paper 120

## Investigating the Use of Electronic Documents in the Jordanian Construction Projects

Hesham Ahmad<sup>1</sup>, Maha Ayoush<sup>2</sup> and Abeer Elhour<sup>3</sup>

### Abstract

Construction processes normally require large exchange of information among project parties on a daily basis. The wide development in Information and Communication Technology (ICT) in recent decades has helped to provide easy processing of data during the life-cycle of construction projects. However, traditional manual methods of filing are still common in the construction industry. The aim of this study is to investigate the use of different electronic documents in the construction projects. A quantitative survey was conducted with 91 respondents from the construction projects' engineers and practitioners. Also, the questionnaire survey investigates if there is an Electronic Document Management System (EDMS) applied in construction projects. Finally, the types of electronic files and the extent of using electronic-based documents were investigated. The results of this study help to understand the context of the documents in the construction projects that may be useful to seek opportunities for improvement, and provide effective solutions for EDMS application.

**Keywords:** information and communication technology, construction projects, questionnaire survey, document management system.

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## Paper 128

# Extracting Construction Knowledge from Project Schedules using Natural Language Processing

Xiaojing Zhao<sup>1,2</sup>, Ker-Wei Yeoh<sup>3</sup> and David Kim Huat Chua<sup>4</sup>

## Abstract

A sound and good quality schedule is critical to the success of a construction project. However, the little time available for proper project scheduling in the planning and design stage often impairs the quality of a schedule. Few efforts have been made to evaluate and maintain the schedule quality in the construction stage. Usually project teams need to put intensive manual efforts to conduct schedule quality diagnosis which is time-consuming and subjective to a large extent. One major challenge of diagnosing schedule quality is understanding the activity characteristics and construction logic. The multi-partite nature of construction projects (i.e. schedulers and project teams) further exacerbates the difficulty of diagnosis. This paper thus proposes a novel semantic-based logic reasoning and representation methodology to extract construction methods from the schedule to ensure a consistent project schedule. The intellectual contributions of this paper are twofold. First, this paper develops an ontology of tasks with hierarchies from the schedule to automatically extract the construction methods and activities. Second, this paper presents a novel dependency-based information representation schema for representing the logics between tasks and key constraints to facilitate the complete automation in construction logic reasoning from the schedule. To test the proposed system, this paper evaluates the average rate of recall and precision achieved by the system for extracting construction activities and logics in the schedule within one month and compared the results with the rate achieved by manual check. The developed system provides both academics and practitioners a method to detect the deficiencies of project schedules and assists project planners to produce and maintain good quality schedules starting from project initiation until its completion.

**Keywords:** Schedule quality, Construction project, Automatic reasoning, Ontology learning, Construction knowledge

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## Session 2-A

### 4 September 2019

10:00-12:00

20	<p style="text-align: center;"><b>A Child Knee Orthosis Design and Simulation based on Dynamic Considerations</b></p> <p style="text-align: center;">Cristian Copilusi, Nicolae Dumitru, Alexandru Margine, Adrian Rosca, and Eugen Rosu</p>
36	<p style="text-align: center;"><b>Kinematics and design of a leg exoskeleton for human motion assistance</b></p> <p style="text-align: center;">Ionut Geonea, Nicolae Dumitru, Cristian Copilusi , Alexandru Margine, and Laurentiu Racila</p>
58	<p style="text-align: center;"><b>Influence of hot-dip galvanizing on mechanical properties of pressure-locked gratings</b></p> <p style="text-align: center;">Paweł Krupicz</p>
84	<p style="text-align: center;"><b>Additive manufacturing for cost efficient hybrid welding jigs</b></p> <p style="text-align: center;">Achim Kampker, Georg Bergweiler, Ansgar Hollah, Kolja Lichtenthäler, and Sebastian Leimbrink</p>
86	<p style="text-align: center;"><b>An investigative study on production of a composite novel plant fibre: Mechanical properties comparison</b></p> <p style="text-align: center;">Olehile Kaelo and Vuyo T. Hashe</p>
133	<p style="text-align: center;"><b>Combining takt and Deming cycles at operator level – practical study</b></p> <p style="text-align: center;">Jon Lerche, Hasse Neve, Søren Wandahl, and Allan Gross</p>
143	<p style="text-align: center;"><b>State-of-the-art in Product-Service System Design</b></p> <p style="text-align: center;">Mariusz Salwin (Warsaw University of Technology)*; Andrzej Kraslawski (Lappeenranta University of Technology); Jan Lipiak (Warsaw University of Technology)</p>
144	<p style="text-align: center;"><b>A System Dynamics Model of Multimodal Transportation of Rubber Products in Thailand</b></p> <p style="text-align: center;">Thanwadee Chinda, Chinakrit Tangkunapipat, Pichaporn Tirakothai, Nawisa Matchacham, Natthanan Siriphattanakulkajorn, and Katawut Noinonthong</p>
66	<p style="text-align: center;"><b>Lean Industry 4.0 – wastes versus technology framework</b></p> <p style="text-align: center;">Krzysztof Ejsmont and Bartłomiej Gładysz</p>
104	<p style="text-align: center;"><b>Bridging Strategic Project Planning with Operative Planning in the Design Process</b></p> <p style="text-align: center;">Kai Haakon Kristensen and Bo Terje Kalsaas</p>
50	<p style="text-align: center;"><b>Prefabrication and Waste Minimisation in Construction Projects: Perspectives from New Zealand</b></p> <p style="text-align: center;">Olivia Luo and Wajiha Shahzad</p>

## Paper 20

## A Child Orthosis Design and Simulation based on Dynamic Considerations

Cristian Copilusi<sup>1</sup>, Nicolae Dumitru<sup>2</sup>, Alexandru Margine<sup>3</sup>, Adrian Rosca<sup>4</sup> and Eugen Rosu<sup>5</sup>

### Abstract

This paper addresses a knee orthotic system design used on a 4-year-old child with locomotion problems. This knee orthotic system design was made by performing a dynamic analysis of the proposed child locomotion system. The aim of this dynamic analysis was to obtain knee joint connection forces in case of a walking activity. For the proposed dynamic model, input data such as hip, knee and ankle joint motion laws were considered. These were obtained through an experimental analysis with a high-speed video camera equipment on a healthy child. Thus, a database was created, which was used as input data for numerical simulations made in a dynamic mode with MSC Adams. Through these numerical simulations, important results were obtained, and these will further validate the proposed prototype.

**Keywords:** dynamics, mechatronic system, locomotion system, multibody systems, knee orthosis.

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## Paper 36

# Kinematics and Design of a Leg Exoskeleton for Human Motion Assistance

Ionut Geonea<sup>1</sup>, Nicolae Dumitru<sup>2</sup>, Cristian Copilusi<sup>3</sup>, Alexandru Margine<sup>4</sup> and Laurentiu Racila<sup>5</sup>

## Abstract

This paper presents studies concerning the design of exoskeletons for human lower limb motion assistance. A study concerning the structural and mechanical design in Solid Works is presented on the first part of the paper. In the second part, a human gait motion analysis with goniometer sensors is performed. Also, a kinematic characterization for the new proposed leg exoskeleton is performed. The exoskeleton achieved design is based on a seven-link mechanism, designed to accomplish requirements of human locomotion. The kinematic computational model and the obtained results with plots in ADAMS software are presented. The obtained simulation results are compared with experimental human gait, and they are useful to characterize the exoskeleton motion and to demonstrate suitable performance for human rehabilitation purposes.

**Keywords:** design, kinematics, dynamics, exoskeleton, rehabilitation.

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## Paper 58

# Influence of hot-dip galvanizing on mechanical properties of pressure-locked gratings

Pawel Krupicz<sup>1</sup>**Abstract**

Pressure-locked gratings are made by pressing cross bars into tapered slotted bearing bars under high pressure. The end result is a grate with rectangular meshes. Grating design process is based on the assumption that the load is carried by the bearing bars. Grating as a final product is protected against corrosion, usually using hot-dip galvanization. Comparative observation of non-galvanized and hot-dip galvanized gratings shows that zinc not only forms a thin coating on the whole surface of bearing and cross bars, but also fills the voids located in the joints of the bearing and cross bars. Steel changes its properties due to high temperature in the hot-dip galvanization process. Additionally, during the technological process the material of a bearing bar is subject to plastic deformations. Therefore it can be assumed that the above mentioned changes affect the mechanical properties of the grating, especially its stiffness and strength. However, grating design process includes only strength characteristics of non-galvanized bearing bars, determined by steel grade.

The aim of the paper is to investigate effect of hot-dip galvanizing on the mechanical properties of gratings and make the recommendations for their production. The paper compares the results of tensile tests of samples of non-galvanized bearing bars without heat treatment, non-galvanized bearing bars subjected to hot-dip galvanizing temperature and hot-dip galvanized bearing bars. The assembled samples of hot-dip galvanized steel gratings and non-galvanized steel gratings were subjected to a bending test. There was a significant increase in the stiffness of the hot-dip galvanized grating. Calculation coefficient was proposed to be included in the design stage of production process to incorporate increase of stiffness of galvanized grating caused by hot-dip galvanization. Guidelines are presented how include results of the work in the production management of galvanized steel products manufacturing.

**Keywords:** hot-dip galvanizing, pressure-locked steel grating, steel, mechanical properties, production management

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## Paper 84

# Additive Manufacturing for Cost Efficient Hybrid Welding Jigs

Achim Kampker<sup>1</sup>, Georg Bergweiler<sup>1</sup>, Ansgar Hollah<sup>1</sup>, Kolja Lichtenthäler<sup>1</sup> and Sebastian Leimbrink<sup>1</sup>

## Abstract

The use of the Additive Manufacturing (AM) process Fused Filament Fabrication (FFF) for the manufacturing of pre-series welding jigs for car body assemblies shows potential in terms of cost reduction and design flexibility. A conventional welding jig consists of standard parts and machined parts which can cause high costs in manufacturing. Although many simpler 2D parts which can be cut very economically are used as well, some of those parts have to be machined again in order to integrate all functional features. Additional manufacturing steps cause additional costs and prolong the supply process of those parts. A hybrid jig system that consists of part specific FFF components and standard elements has been developed for the welding of car body assemblies in the pre-series vehicle production. In order to analyse cost and time advantages, an economic assessment is used. It is aimed to determine whether the use of a hybrid jig system for welding operations of car body prototypes generates lower financial and time expenditures compared to conventional welding jigs. The assessment includes a detailed comparison between the manufacturing of a hybrid welding jig and a conventional welding jig for car body assemblies. Additive Manufacturing (AM) of the complex and specific parts with FFF offers time and cost advantages because material and process costs are lower than with milling, and process chains can be simplified. This paper presents the results of the assessment on the hybrid welding jig system and shows the overall potential in the pre-series vehicle production.

**Keywords:** additive manufacturing, body shop, fused filament fabrication, welding jig

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## Paper 86

# An Investigative Study on Production of a Composite Novel Plant Fibre: Mechanical Properties Comparison

Kaelo Olehile <sup>1</sup> and Vuyo Terrence Hashe <sup>2</sup>**Abstract**

This paper introduces a production process of identifying and producing a novel natural fibre from an indigenous source tree with the intention of reducing the dependency on imported high-quality natural fibres from outside Africa. Commercialized plant fibres from plants like Sisal generate income for their host countries in Central American and European regions. This plant is used in polymer matrix composites as a load-bearing member. This paper identified three plants – Sparmania Africana, Ficus lutea and Ficus sur, of which only the Ficus trees were investigated. The properties investigated were the uniaxial tensile strength and Young's Modulus as these properties enabled the researchers to characterise the material strength. The Ficus lutea out-performed the Ficus sur in terms of the true strength and the engineering strength. The two are almost the same for both materials at 97% when compared. On average, maximum strength is about 22.6 and 17.5 MPa at breaking, with Ficus lutea greater than Ficus sur. Research is statistically valid with a P-value of less than 0.05, this paper achieved a P-value of 0.001162. In addition, the two Ficus plants did not perform well when compared to Sisal plant.

**Keywords:** natural fibre, plants, properties

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Paper 133

## Combining takt and Deming cycles at operator level – practical study

Jon Lerche<sup>1</sup>, Hasse Neve<sup>2</sup>, Søren Wandahl<sup>3</sup> and Allan Gross<sup>4</sup>

### Abstract

Few empirical studies have previously been reported on implementation of takt planning and controlling the workflows continuously. This paper presents a case study from the offshore renewable industry, which is closely related to construction. The paper aims to develop and trial a conceptual model for combining takt planning and PDCA, also known as the Deming cycle in construction environments. The conceptual model has furthermore been modified for a visual board implementation that covers a specified process with a fixed number of technicians per performing team. The conceptual model draws on knowledge of takt planning implementation from the lean construction community and PDCA implementation from the lean production community. The main contribution of this paper is the conceptual model combining takt planning and Deming cycle in a construction environment. This conceptual model has potential implications in the construction and refurbishment industry.

**Keywords:** Construction, Deming, Management, Offshore, Takt

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## Paper 143

**State-of-the-art in Product-Service System design****Mariusz Salwin<sup>1</sup>, Andrzej Kraslawski<sup>2,3</sup> and Jan Lipiak<sup>4,5</sup>****Abstract**

Since the 1990s, a Product-Service System (PSS) has been seen as a concept that helps businesses in building their competitive advantage and allows them increase the added value provided to customers by expanding product offer with dedicated services within an environmentally-friendly model. The needs voiced by practitioners and theoreticians concerning the development of new PSS models for different industries have not been met satisfactorily as many theoretical, methodological, and practical aspects involved in the process remain unresolved. The paper proposes a comprehensive classification of PSS design methods. The latter have been classified against criteria, such as, e.g., industry, size of a company, in which PSS models can be applied, product and service development paths or types of contacts with customers. In addition, the paper reviews literature on PSS design published over recent 18 years. Its primary purpose is to identify the major aspects of PSS design, features common to different design methods, and their limitations. By examining the existing design methods we hope to facilitate the adaptation of business models to specific PSS problems. This publication addresses and analyses 60 PSS design methods.

**Keywords:** Product-Service System, Product-Service System design, Product-Service System method.

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## Paper 144

## A System Dynamics Model of Multimodal Transportation of Rubber Products in Thailand

Thanwadee Chinda<sup>1</sup>, Chinakrit Tangkunapipat<sup>2</sup>, Pichaporn Tirakothai<sup>3</sup>, Nawisa Matchacham<sup>4</sup>, Natthanan Siriphattanakulkajorn<sup>5</sup> and Katawut Noinonthong<sup>6</sup>

### Abstract

Thailand is the world's leading natural rubber exporting country, accounting for 36.8% of the world market. In addition, the country is a member of the ASEAN Economic Community, aiming to be the center of the transportation in the region. Multimodal transportation is then encouraged to enhance the transport efficiency and reduce the logistics cost. This study develops the system dynamics model of multimodal transportation of rubber product in Thailand, utilizing the system dynamics modeling approach. Six savings and five costs related to the multimodal transportation are considered in the model. The simulation results show a negative cash flow at the beginning of the simulation years due to high investment in the multimodal-related facilities and infrastructure. With continuous use of multimodal transportation, the net cash flow becomes positive, and the project reaches the internal rate of return of 12% at the end of year 13. The results also show that the saving in truck rental cost and the product damage cost are the most important benefit and cost of multimodal transportation, respectively. The study results can be used as a guideline for the rubber and exporting companies, as well as the government, to effectively plan for the multimodal transportation in the long-term.

**Keywords:** multimodal transportation, rubber, system dynamics modeling, Thailand

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Paper 66

## Lean Industry 4.0 – Wastes versus Technology Framework

Krzysztof Ejsmont<sup>1</sup> and Bartłomiej Gładysz<sup>2</sup>

### Abstract

Both lean management and Industry 4.0 are obviously important in practices of modern manufacturing companies. Lean management is a well-known and deeply researched approach while Industry 4.0 is also well recognized, but still relatively new with a big part of the theory and practice to be developed, validated, verified and applied. However, Industry 4.0 gains more and more interest of both researchers and practitioners and is very important for manufacturing and other industries. The main goal of this paper is to analyze synergies, or deficits, of lean management and Industry 4.0. For this purpose, a lean framework for waste typology was combined with the Industry 4.0 potential to decrease those wastes. It was also analyzed if some properties of Industry 4.0 may lead to increase in some types of waste. Each type of waste was analyzed to consider its possible decrease and increase through the application of Industry 4.0 grounding of field practice and literature analysis.

**Keywords:** Industry 4.0, lean management, lean manufacturing, waste.

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Paper 104

## **Bridging Strategic Project Planning with Operative Planning in the Design Process**

**Kai Haakon Kristensen<sup>1</sup> and Bo Terje Kalsaas<sup>2</sup>**

### **Abstract**

The paper studies the issue of bridging strategic planning with operative planning in the design process of complex AEC-projects. The paper present user-friendly planning methods on an operative level which gives the planner intuitive control over dependent, independent, and interdependent tasks during the design process. In our understanding the planning process starts at the strategic level using integrated milestones as a prerequisite for handling progress and strategic coordination in projects. Moving forward in the planning process towards the operative level, the process requires flexible and agile methods which ensures robustness in the various plans that must be made. In this paper we will address the design phases between front-end planning and project execution. The design science research approach is applied. The paper adds to the body of knowledge practical methods and tools suited for efficient planning of the design process. Our study contributes both to theory and practice regarding development of tactical planning in the design processes.

**Keywords:** design, planning, control, milestones.

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Paper 50

## **Prefabrication and Waste Minimisation in Construction Projects: Perspectives from New Zealand**

Olivia Luo<sup>1</sup> and Wajiha Shahzad<sup>2</sup>

### **Abstract**

The benefits of prefabrication are well known and include increased efficiency, greater economy, and safety in construction operations. There have also been anecdotal references to the reduction of construction waste as a result of prefabrication but there are little empirical studies to support this assertion. The current study undertakes an investigation to establish the influence, prefabrication can have on the amount of construction waste generation. Data was gathered through the collation of the perspective views of 47 construction practitioners and stakeholders who have professional experience in the New Zealand construction industry. Quantitative method of analysis was chosen for ease of understanding. The results indicated greater levels of prefabrication corresponded to lower levels of construction waste generation. However, the key to achieving construction waste minimisation targets lies in better supervision of the quality of prefabricated products. The study concludes that more training, education, and awareness is needed within the prefabrication sub-sector to realise waste minimisation on construction projects.

**Keywords:** construction waste, prefabrication, New Zealand, waste minimisation.

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## Session 2-B

### 4 September 2019

14:15-15:45

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	John Smallwood
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Paper 12

## Construction Project Manager (CPM) Contributions to Construction Health and Safety (H&S)

John Smallwood<sup>1</sup>

### Abstract

The construction project manager (CPM) identity of work (IOW) records a range of H&S actions required of CPMs throughout the six stages of projects. Furthermore, CPMs as project leaders, are in a unique position to integrate H&S into the six stages of projects. Given the afore mentioned, a study was conducted to determine the nature and extent of CPM contributions to construction H&S. A self-administered questionnaire survey delivered per e-mail, was conducted among a convenience sample stratum consisting of CPMs. The salient findings include that: seven project parameters are important to CPMs; CPMs consider / refer to H&S primarily during construction documentation and management, and tender documentation and procurement, in terms of project stages; CPMs generally undertake 'designing for construction H&S'-related actions relative to their projects / practices, and CPMs are knowledgeable with respect to project managing construction H&S, risk management, and constructability reviews, however, less so relative to the influence of design on construction H&S. The study concluded that CPMs consider / refer to H&S, there is more focus on H&S during procurement and construction, than design, and CPMs do understand and appreciate the need to integrate H&S into construction project management. The study indicates a need for enhanced integration of H&S into the first three stages of projects, and the upstream design aspects such as concept design.

**Keywords:** Construction, Health and Safety, Project Managers.

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## Paper 13

# The Role of Procurement in Construction Health and Safety

John Smallwood<sup>1</sup> and Claire Deacon<sup>2</sup>**Abstract**

Relative to other industries in South Africa and construction industries worldwide, the construction process generates a disproportionate number of fatalities, injuries, and disease and both the direct and indirect costs contribute to the cumulative cost of construction. Literature indicates that globally, procurement influences construction H&S, including issues such as pre-qualification, reference to construction H&S in conditions of contract and contract documentation, facilitation of financial provision for construction H&S, assessment thereof, and reporting thereon. A study was conducted among delegates attending a two-day summit to determine their perceptions relative to the role of procurement in construction H&S, and whether the summit had an impact, or not. The following constitute the salient findings. Delegates do have an understanding and appreciation of the role of procurement in construction H&S, and the multi-stakeholder nature of construction H&S. Furthermore, the summit did have an impact in terms of inducing a change in the delegates' culture. The paper concludes that: all stakeholders influence construction H&S; pre-qualification of all stakeholders in terms of construction H&S is important; construction H&S should be considered or referred to during all six project stages, in conditions of contract, contract documentation, and when deliberating project duration; financial provision for construction H&S should be facilitated and assessed; supply chain management within the context of construction H&S is critical; construction H&S performance should be assessed throughout projects, and be addressed in close out reports. Recommendations include: partnering as a process that includes H&S should be implemented on projects; multi-stakeholder project H&S plans should be compiled for projects, and more emphasis should be placed on construction H&S during the procurement process.

**Keywords:** construction, health and safety, procurement.

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Paper 122

# Improving Collaboration in Construction Projects in Developing Countries: The Case of Kurdistan Region of Iraq

Hazhar Faris<sup>1</sup>, David Hutchinson<sup>2</sup> and Mark Gaterell<sup>3</sup>

## Abstract

The construction sector is criticised for being fragmented and for having a large number of problems between stakeholders such as adversarial relationships, lack of trust and ineffective communication. These issues emerge especially in developing countries. Collaboration has been introduced as a solution to such issues. However, delivering an effective process of collaboration is a challenge with a wide range of factors involved. This paper identifies and sorts the critical factors that affect collaboration in the construction sector and recommends ways to adapt such factors in the sector. Through a comprehensive review of the literature, two groups of critical success factors have been identified to improve such practices, hard factors and soft factors. This study contributes to the scarce literature about collaboration in the construction industry in the Kurdistan and identifies factors of collaboration that construction projects need to adopt in order to improve their performance.

**Keywords:** Collaboration, critical factors, construction, developing countries, Kurdistan-Iraq.

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Paper 106

## Comparative Analysis of Mega Road Construction Projects in Term of Innovation

Una Obiose Kriston Nwajei<sup>1</sup> and Bo Terje Kalsaas<sup>2</sup>

### Abstract

This paper examines, using critical realism, the causes and mechanisms of innovation in three civil road construction projects. Its focus is to examine how value can be created within the design process through innovation. Emphasis is placed on procurement and the Best Value Procurement (BVP) process, as it is the first case of its use in Norwegian road construction projects. Data was collected through surveys and interviews. Findings indicate that procurement using early involvement is very innovative in the design process yet must be adapted, to allow for early planning, to foster innovative solutions. However, there are also some contributing causes towards a lack of innovation due to the strategic choices within the projects, such as the execution model, the commercial incentives and the contract type. Additionally, the amount of government regulation and approval that is needed for innovation to occur hinders the process. The results help to identify that the mechanisms for innovation can be found in the availability of resources, time and money and that learning and the ability to share and communicate tacit knowledge is a key mechanism for creating value in projects.

**Keywords:** BVP, incentives, innovation, mechanisms, value creation

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## Paper 16

# Applying Mixed Methods Sequential Explanatory Design to Innovation Management

Warit Wipulanusat<sup>1</sup>, Kriengsak Panuwatwanich<sup>2</sup>, Rodney Stewart<sup>3</sup>, and Jirapon Sunkpho<sup>4</sup>

## Abstract

This article discusses a procedure of mixed methods sequential explanatory design used to conduct sequential QUAN → QUAL mixed methods study. The methodological procedures are explained using a mixed methods study of innovation in the Australian Public Service (APS). The sequential explanatory design incorporated quantitative and qualitative approaches in two consecutive phases within one study. The quantitative method (i.e. questionnaire survey) was conducted in the first stage, followed by the qualitative approach using thematic analysis. The questionnaire survey data to be complemented by an archival analysis approach under a two-phase analysis. The archival analysis provided fresh context to understand the innovation process in the APS. The findings from both phases of the study were then examined and combined to draw the conclusions. This study made several contributions to the body of knowledge related to research methodology by not only adopting a quantitative-dominant mixed method approach, but also by employing integrated methods used for a deeper understanding of the impact of socio-psychological constructs on workplace innovation and career satisfaction.

**Keywords:** innovation, mixed methods research, sequential design

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## Paper 82

# Application of Reliability Engineering in a Chemical Plant to Improve Productivity

Vuyo Terrence Hashe<sup>1</sup> and Makgomo Thelma Mamatlepa<sup>2</sup>

## Abstract

This paper is based on reliability case study conducted in a chemical company (Company X) based in Germiston South Africa. The work conducted focused on the causes of production loss due to poor equipment reliability that lead to downtimes. In the chemical, the production team generates works orders through an autonomous maintenance exercise which is aimed at identifying potential equipment defaults before they cause a breakdown. The works orders are categorized under corrective maintenance schedule. There are also time based preventative maintenance works orders that are created on System Application Program (SAP) for critical equipment and their components. More often, the response time from the maintenance team is slower and leads to subsequent breakdowns and production stoppages. The financial documents of the chemical plant showed that on average the plant spends \$31 000 per month on maintenance cost. Projections indicate that this could easily amount to more than \$376 000 per annum provided that there is no mid-term to long-term intervention to address equipment failures. The main objective of this study is to investigate the causes of reoccurring system failures using the reliability concepts and provide a solution specific to Company X which could be expanded to other companies and industries. This study followed both a qualitative and descriptive case study research approach. Data collection was carried out by attending to equipment breakdowns, observations during the normal daily operations, during production times, studying the historical available maintenance and technical relevant data, staff interviews, company internal information regarding the financial spending for the year of study. Finding indicated that the plant maintenance programmes were inadequate and needed to be revitalised by the introduction and implementation of reliability centred maintenance (RCM) process. The RCM process was suggested to address the issue of identifying key priority equipment responsible for major downtimes and analysing the failure modes so to suggest corrective actions before failure occurs.

**Keywords:** downtime, maintainability, reliability

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Paper 100

## Major Influencing Factors of Decision about Alternative Technical Means in Selected Aviation Services

Eugeniusz Piechoczek<sup>1</sup> and Andrzej Hawryluk<sup>2</sup>

### Abstract

The paper presents general assumptions and continued results of the studies on theoretical and practical aspects of providing selected services with alternative technical means. The study purpose was based on SWOT analyses and research within customers and suppliers. The specificity of the assumptions in the selected areas was illustrated on the basis of examples of completed undertakings. Additionally, the article contains a list of examined factors influencing the adaptation of Unmanned Aircraft Systems as components of the model of conversion of services that could have an impact on decision-making in terms of applications of alternative air platforms.

Specific conditions for the chosen area induce the building of the base of rules and the base of knowledge in the range of applying the alternative technical means. It will be essential to preparation of the standards of the approximate inference leaning on insecure or incomplete knowledge. The article bring forward the preliminary results of research and development in this area.

**Keywords:** aviation, service provision effectiveness, Unmanned Aircraft Services, air services, Remotely Piloted Aircraft Systems

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## Paper 114

## Hedonic Model for Off-Campus Student Housing Around Thammasat University, Rangsit Campus

Suthathip Suanmali<sup>1</sup>, Thidaporn Anantasa, Sukolrat Bovornsantisuth, and Suchawadee Diloklap

### Abstract

Thammasat University (TU) is one of the oldest and most well-known universities in Thailand. The Rangsit campus of TU has the largest number of students. The area around the campus has continuous development, which convinces people to come for studying and living around this area. With the increasing population in the area, the demand for residences has also increased. The dormitories of the TU Rangsit campus can accommodate a limited number of students. Therefore, the off-campus residences, for instance, an apartment or a condominium is an alternative for students. This research studies the current trend of the facilities provided by apartments and the significant factors affecting the rental price. Thirty-two independent parameters are collected from all apartments around the TU Rangsit campus. Multiple linear regression is employed to analyze the significant factors that affect the rental price. The average rental price per month is 8,079.40 Baht (260 dollars), and the average rental price per square meter is 226.85 Baht (7.30 dollars). The results indicate that the significant factors affecting the rental price are free Wi-Fi availability in the shared-common area, convenience store under the building, location, monthly maintenance price, being next to a main road, age of establishment, water heater, fitness facility, recent renovation, refrigerator, swimming pool, laundry and dry-cleaning service, and restaurant under the building.

**Keywords:** Hedonic model, marginal utility, multiple regression, off-campus housing

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Paper 115

# The Optimal Initial Buffer and Cycle Time Design for Improving Lean Production Automation Line Efficiency

Duong Vu Xuan Quynh<sup>1</sup> and Chawalit Jeenanunta<sup>2</sup>

## Abstract

Optimizing the size and location of storage buffer between machines is critical issues in designing efficient production automation line. The objective of the study is to propose the optimal design of the initial buffer size as well as the suitable machine cycle time to increase the efficiency of the automation line. In this study, the production system consists of three machines with two buffers are placed between them is considered. There is a regular downtime for maintenance at the second machine, which results in lower production efficiency. The production simulation on cloud is used for modelling and demonstrating the concept. The experimental results revealed the proposed optimal initial buffer and the proposed cycle time of maintenance station could yield the maximum production line efficiency.

**Keywords:** Buffer Design; Simulation model; Production line efficiency

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## Session 2-C

### 4 September 2019

16:00-17:00

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	Leonas Ustinovichius and Czesław Miedziński
X2	<b>Forecasting environmentally friendly economic growth with DEA</b>
	Joanicjusz Nazarko and Ewa Chodakowska
X3	<b>A Hybrid Approach in Future-Oriented Technology Assessment</b>
	Ewa Chodakowska and Joanicjusz Nazarko
X4	<b>Increasing Container Transshipment Terminal Effectiveness and Sustainability by Application of Unmanned Vehicles (UVs)</b>
	Katarzyna Anna Kuzmich
68	<b>Proposed Risk Management Decision Support Methodology for Oil and Gas Construction Projects</b>
	Mohammed K. Al Mhdawi and Ibrahim Motawa
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	Zeeshan Ullah

## Paper X1

# BIM Prototype System Creating for the Optimization of Integrated Construction Processes in the Technology of Extended Reality

Leonas Ustinovichius<sup>1</sup> and Czesław Miedziałowski<sup>2</sup>

## Abstract

Models with expanded building information are the most advanced technology in the construction industry. The problem that should be solved now is the creation of software that will allow to improve the efficiency of construction works, adjusting them to the current situation in an optimal way. For this reason, there is a need to develop automatic solutions for real construction sites that will ensure comprehensive selection of optimal solutions, that will calculate the demand, define storage areas, roads, temporary communication and fences and deploy machines and devices on the construction site. The construction site planning process is not identical for each construction. That is why there is a need to create an IT system that optimizes integrated building processes in an augmented reality environment. As part of the project, three basic elements were identified. The first is to create an automatic generation system of bid documents that involves executing, bill of quantities, costing, schedules and integrated work time management as well as the structure classifier of the company. The second element within the framework of the project is the construction organization with an automated system that manages the executive documentation of the construction organization, which includes: development of the construction site for the time of earthworks (excavations), construction works and finishing works. The forms of the results of the computational and descriptive and graphic parts, as well as the automatic construction of the schedule and cost estimate for the development of the construction site will be developed. The achieved results will enable the implementation of the third element, called the automated system for managing the construction process, which will analyze the quantity and quality of work, complete the electronic construction logbook, facilitate management of the construction materials and human resources, as well as issuing the invoices.

**Keywords:** BIM, Extended Reality, Optimization of Integrated Construction Processed.

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## Paper X2

**Forecasting environmentally friendly economic growth  
with DEA**Joanicjusz Nazarko<sup>1</sup> and Ewa Chodakowska<sup>2</sup>**Abstract**

Increasing awareness of the importance of environmental issues, the undisputed link between economic growth and climate change associated with CO<sub>2</sub> output have led to the development and use of more environmentally friendly technologies with lower greenhouse gas emissions. However, the global trend of reducing CO<sub>2</sub> emissions per one dollar of GDP is not always reflected in the situation of individual countries. Trends in the time series of economic growth and CO<sub>2</sub> emissions vary between countries. The analyses of CO<sub>2</sub> and other greenhouse gases emissions are the subject of numerous publications that include both simple and more sophisticated comparisons, quantitative and qualitative forecasts and scenarios, as well as attempts to indicate the far-reaching effects of the adopted development path. The article proposes a method that has not been used in this area so far – Technology Forecast Data Envelopment Analysis (TFDEA) to assist in achieving the desired changes in the relation between gross domestic product (GDP) and CO<sub>2</sub> emissions on the basis of historical data. Presented approach allows multi-dimensional comparisons of growth paths of both developed and developing economies. The article contributions are the systematic review of current TFDEA applications, the presentation of TFDEA with UML nations and the novel area of use the TFDEA with recommendations.

**Keywords:** CO<sub>2</sub>, GDP, forecasting, TFDEA.

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Paper X3

# A Hybrid Approach in Future-Oriented Technology Assessment

Ewa Chodakowska<sup>1</sup> and Joanicjusz Nazarko<sup>2</sup>

## Abstract

Technology Assessment has been a growing field of study for the few past decades. Intensive work on solving the problem of proper technology assessment has translated into the development, improvement or adjustment of the method and models used in technology evaluation projects. The article aims to present a new hybrid model that uses the Rough Sets approach and the DEA method to increase the objectivity in the selection of priority technologies in future-oriented technology assessment projects. Real-data application proved that this model: (i) reduces the number of considered assessment criteria by a few times without a significant change in technology rankings; (ii) gives individual objective weights to the criteria and allows highlighting the "strengths" of each technology; (iii) from the point of view of efficiency, considers the attractiveness of the development of each technology and the rationality of allocating resources required for the development; (iv) allows the inclusion of a possible contradiction among expert opinions.

**Keywords:** Future-Oriented Technology Assessment, Data Envelopment Analysis, Rough Sets, model.

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Paper X4

# Increasing Container Transshipment Terminal Effectiveness and Sustainability by Application Of Unmanned Vehicles (UVs)

Katarzyna Anna Kuzmicz<sup>1</sup>

## Abstract

Increasing volume of intermodal transportation sets pressure for organisational and technological improvements to meet the rising demand. The general idea of using robots to support human activities is also implemented in logistics. Although there are constraints connected with limited trust to unmanned vehicles for safety reasons, container transshipment terminals seem to be a suitable space for their application due to possible limitation of human presence in the area of their activity. In this paper an organisation of the processes at a container transshipment terminal with application of ground and aerial unmanned vehicles is presented. The main areas of implementing unmanned ground vehicles (UGVs) is container handling. Unmanned aerial vehicles (UAVs), or drones, are used for traffic flow monitoring, reaching places difficult or risky for people, such as dense stacking areas, or crane inspections. They can also serve to protect security of containers or prevent safety risks concerning people in the terminal. The outcomes of the study point to the increase of effectiveness and safety of terminal operations, as well as lowering costs and detrimental effects on environment.

**Keywords:** container transshipment terminals, unmanned vehicles, drones

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## Paper 68

# Proposed Risk Management Decision Support Methodology for Oil and Gas Construction Projects

Mohammed K. Al Mhdawi<sup>1</sup> and Ibrahim Motawa<sup>2</sup>

## Abstract

Oil and gas construction projects are complex and risky due to their dynamic nature and environment, as they involve a considerable number of stakeholders. The contracting companies in Iraq find many challenges when managing the risky events in an environment that categorized with poor supplies, security threats, unskilled workforce and logistics difficulties. Evidence in the literature indicates that there is a lack of unified methodology for project management and especially for risk management in Iraq. Also, the rise in the global energy demand increases the need for a workable, effective and efficient risk management methodology for such projects. Thus, the purpose of this research is to develop an integrated decision support methodology for managing the risk factors in oil and gas construction projects in Iraq. The proposed methodology has been developed to support the local and international contracting companies working in Iraqi oil and gas fields when making decisions regarding the risk factors during the project life cycle. The proposed methodology consists of the following phases: risk planning, risk identification using documentation review and expert interviews, risk analysis using a multi-criteria risk analysis model based on fuzzy set theory, risk effect prediction on project time and cost using artificial neural network (ANN), selection of risk response actions using Gravitational Search Algorithm (GSA) optimization technique and finally, designing an integrated web-based risk management decision support platform. The adopted methodology will enable decision makers to assess the oil and gas projects risky events, support their decision during planning and work implementation stages, gain experience in risk management through exercising and implementing risk management on scientific and documented bases; organize and document the knowledge-based information for decision makers.

**Keywords:** Oil and Gas, Project management, Risk management, Decision support system

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## Paper 70

## Assessment of Risk Management Practices in Construction Industry

Mohammed K. Al Mhdawi<sup>1</sup>, Ibrahim Motawa<sup>2</sup> and Hatem A. Rasheed<sup>3</sup>

### Abstract

The construction industry is globally known as a risky industry because construction projects usually accompanied with high uncertainty in achieving their final objectives (time, cost and quality). The main purpose of this research is to investigate the current practices and methodologies of risk management for the construction industry in Iraq. A mixed research method that involves both qualitative and quantitative approaches is adopted in this research to collect and analyses the primary data. A comprehensive review of the available literature of risk management at the international and local construction projects is conducted followed by interviewing experts and carrying out a questionnaire survey with construction professionals in Iraq. The assessment focuses on the following levels: Project management team awareness and understanding of risk management tools and techniques, methods used to identify risks, currently used risk analysis and ranking techniques, risk management monitoring and controlling procedures, the status of risk management for each project phase, contractors role in applying risk management process, and the relation between risk management and project success. It has been found that the use of risk management techniques in building construction in Iraq is low. Most of contracting companies in Iraq are applying qualitative methods when identifying and analyzing the risky events over quantitative methods. The absence of the risk management team within the project management culture, weak risk planning, the lack of risk management training and knowledge within the construction firm were found to be the main barriers preventing the execution of effective risk management process.

**Keywords:** Risk management, risk management, construction projects.

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Paper 129

# How Sustainability in Healthcare Sector Challenges Guidelines and Code Development: A Framework for Design of Sustainable Hospital Buildings

Zeeshan Ullah<sup>1</sup>

## Abstract

It is nowadays an accepted fact that built environment is one of the major anthropogenic exploiters of nature as building consume a great amount of resources in the form of energy, materials and water which ultimately causes GHG emissions, resource depletion and waste generation. The concept of sustainability in building sector has not only put forth a challenge for builders but also the governing bodies that deals with the development of codes, guidelines and building standards. There is now a need to accrue all these standards and technology at one place in a framework which may help as a reference approach to design a wholly sustainable building. This study is based on review of literature where data from published articles, books and official websites of code developing authorities has been collected and investigated particular to the design of sustainable healthcare facilities. The output of this study is a comprehensive yet simple framework for the design of wholly sustainable hospital building which covers all aspects of sustainability and it may give designers and learners a portrayal of the process of designing a sustainable hospital building. This research aggregates all the available standards and guidelines for green and sustainable building design which is a good addition to literature and serve as compact reference for designers/constructors who are willing to adopt sustainable design and construction.

**Keywords:** sustainability, healthcare, green building guidelines, life cycle sustainability assessment.

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