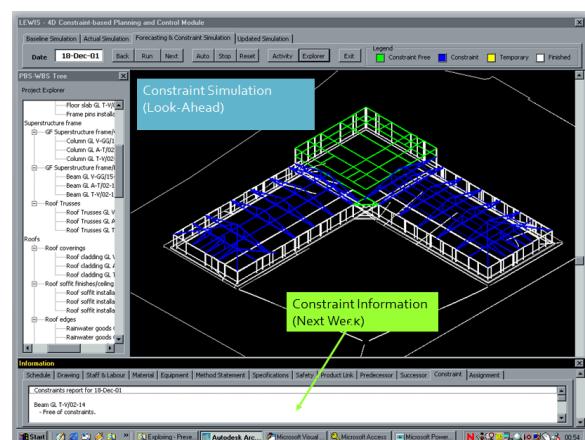


Impact case study (REF3b)

Institution: University of Teesside
Unit of Assessment: 15 – General Engineering
Title of case study: Multi-constraints and multi-dimensional (nD) visual construction planning and coordination approaches and tools.
1. Summary of the impact Research at Teesside University has enhanced sustainability and productivity in construction and related sectors. Between 1998 and 2008, Professor Dawood's research team developed a range of advanced multi-constraint and multi-dimensional visual construction planning and coordination approaches and tools. The global commercial application of this work in Architectural, Engineering and Construction (AEC) organisations has generated a substantial economic impact. For five indicative organisations used as examples in this case study, the impact amounts to more than £1,500,000 in the form of increased turnover, cash injection from technology funds and a spin out company .
2. Underpinning research Three main pieces of research underpinned the impact: 1. Establishment of a Uniclass approach for the integration of product and process data: Between 1998 and 2004, Professor Dawood's team developed a new Uniclass-based approach enabling the development of a number of software tools: ProVis [1], a 4D visualisation tool; the VIRCON (VIRtual CONstruction, EPSRC GR/N00890/01) database; and nDCCIR, which combined these into a single system. The adoption of Uniclass, a standard classification system for the construction industry, allowed the integration of previously disparate information systems providing, for the first time, a medium for integrating visual and project planning, product breakdown (e.g. elements of the building) and work breakdown (e.g. construction operations) structures [1]. Product and process modelling technologies were dynamically linked to the VIRCON database to provide 4D (3D plus time) simulations [1] allowing rehearsal of the building's construction to identify potential clashes and pinch points. The technology developed was tested with the involvement of experts from major construction companies in the UK and Europe (Skanska Construction, Balfour Beatty, AMEC, Ferguson McIlveen LLP, MotEngil, and VSS Civil Engineers) [2]. The work was carried out within a 4-year collaborative research programme with University College London, the University of Manchester (UMIST) and the University of Wolverhampton, as part of the EPSRC-Innovative Manufacturing Initiative. The development of the nDCCIR tool was undertaken through KTP collaboration with Atkins FG (Partnership Number 6486). 2. Development of Multi Constraint Planning Methodology for agile and efficient construction site management: Between 2002 and 2005 the research team developed the approach above into a multi-constraint planning and control methodology bringing together all aspects of the supply chain, ensuring "constraint-free execution" of site assignments. The availability of all necessary elements at the correct time and place substantially reduces wastes and delays on construction sites [3, 4 and 5]. This multi-constraint approach enhances the conventional 3 levels of construction planning (i.e. baseline planning, look-ahead planning, commitment planning) by integrating them with information management systems, 3D models and management theories of optimisation and "Last Planner". This work led to the development of an IT tool, "LEWIS - Lean Enterprise Web-Based Information System", shown above, representing a new generation of planning and control systems overcoming the limitations of traditional project management theory



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and existing information technologies [3].

3. Development of Key Performance Indicators (KPIs) to enable the benefits accruing from these new approaches to be quantified and measured in live projects. Between 2005 and 2009 quantifiable KPIs for the different performance measures (e.g. time, communication efficiency, planning efficiency, cost, productivity, etc.) were developed and used by Prof Dawood's research team to estimate the benefits achievable from the deployment of the multi-constraint planning approaches and tools. The measured KPIs included schedule performance (KPI: "schedule hit rate" – a measure used to identify deviations between actual and planned progress) and communication performance (KPI: time and cost saved in meetings) which were measured in three £multi-million construction projects (£236 million) over a period of 2 years. The results showed a hit rate increase to 72%, a 17% increase compared to the average industry schedule hit rate (55%) and a 30% reduction in the time spent on meetings [6].

3. References to the research

The three papers that best indicate the quality of the underpinning research are [1], [2] and [4]. The work presented in these papers are outputs resulting from EPSRC research project funding (VIRCON EPSRC – GR/N00890/01, £500k total with £120k to Teesside), led by Dawood.

[1] Dawood N., Sriprasert, E., Mallassi, Z. (2002) Development of an integrated information resource base for 4D/VR construction processes simulation. *Automation in Construction*, Vol. 12, pp. 123-131.

[2] Dawood N., Scott, D., Sriprasert, E., Mallassi, Z. (2005) The virtual construction site (VIRCON) tool: an industrial evaluation. *The Journal of Information Technology in Construction*, Vol. 10, pp. 43-54.

The industrial validation of the VIRCON tool presented in this work was supported by an EPSRC Networking grant (£70k to Teesside) led by Dawood.

[3] Sriprasert, E. and Dawood, N. (2003) Multi-constraint information management and visualisation for collaborative planning and control in construction. *The Journal of Information Technology in Construction*, Vol. 8, pp. 341-366.

[4] Dawood N., Sriprasert, E. (2006) Construction scheduling using multi-constraints and genetic algorithms approach. *Construction Management and Economics*, Vol 24 (1), pp. 19-30.

[5] Dawood N. and Mallassi, Z. (2006) Construction workspace planning: Assignment and Analysis Utilizing 4D visualisation technologies. *Computer Aided Civil and Infrastructure Engineering*, Vol 21 (7), pp. 498-513.

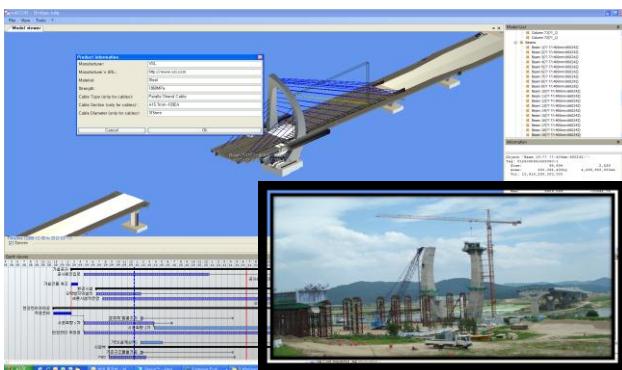
[6] Dawood, N. and Sikka, S. (2009) Development of 4D based performance indicators in construction industry. *Engineering, Construction and Architectural Management*, Vol. 16 (5), pp. 438-458.

4. Details of the impact

The significance of the research findings, their impact on the AEC industry and their extensive dissemination in peer reviewed journals, international conferences and workshops have led to the research outcomes being adopted by a number of major industrial players. The work featured on the UK Prime Minister's Website and in the media [1]. For the organisations involved, the tools developed from the work produced economic benefits, arising from shortened project timeframes, more reliable planning and end dates and consequent minimisation of associated penalties and equipment hire costs; whilst the improved communication efficiency enables improved productivity through reductions in design lead time and wastages associated with design changes. The details of the impact on five organisations is summarised below.

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Dealim Industrial (South Korea), one of the largest industrial conglomerates in South Korea, is using the nDCCIR package on large infrastructure projects (e.g. the 2nd Geumgang Bridge— see company's rehearsal of the bridge using nDCCIR, opposite). The company has also adopted the KPI assessment tools developed by Prof. Dawood enabling them to evaluate the impact. The company achieved a **95% increase in schedule hit rate** leading to **decreased penalty payments and equipment hire costs, 30% decrease in meeting time, and 5% decrease in wastage** related to reduced design changes and rework on site, leading to a **£178,500** increase in profit [2].



Ryder Architecture (UK) is a large architectural company. Between 2009 and 2011 under a KTP project (Partnership Number 7304) **the company adopted the multi-constraint planning methodology** to facilitate improved coordination and management of their design processes. As a result, Ryder achieved an increase of **£249,500** in their turnover, provided employment to **10 new staff members**, and established a **new spin out company** (BIM Academy) to provide new consultancy services to the AEC industry [3].

Datum360 (UK) has been collaborating since 2010 with CCIR researchers under a 3-year KTP project (Partnership Number 8668). During this collaboration the software tools were further developed to incorporate asset management (using class libraries) and commercialised for application in the oil and gas industry. Through the use of this tool, significant business was won with major oil & gas companies such as BP, Tullow, GDF Suez E&P UK Ltd, Chevron and Woodside.

This work resulted in increased turnover for Datum360 of **£448,000 over 2012 and 2013** [4]. Additionally in 2012, as a result of this development, the company received **£500,000** in investment from the Finance for Business North East Technology Fund managed by IP Group [5]. The reach of the work in the oil and gas sector has been extended by collaborative work with the management consultancy, Faithful+Gould, to develop a bespoke visual 5D CAD tool (3D + time + cost) for the oil and gas industry (see opposite) [6].

Deepdale Solutions Ltd (UK) utilised the multi-constraint and visualisation tools for planning and site simulation of a prestigious development in Stratford in 2011/2012 (M8 Hotel). The project was required to deliver a completed building envelope in time to meet the constrained Olympic timetable with the added constraint that simultaneous access to complete the building of the ground and first floor shopping centre was required. These tools enabled Deepdale to identify an alternative installation methodology with prefabricated (unitised) panels for the entire envelope. This led to an estimated reduction of **30% in site time** compared to their previous **norms**, and a **saving of £140,000 in time-related activities** (i.e. reduction in the number of site operatives; reduction of manual handling and its associated health and safety implications; elimination of the need for external means of access/scaffolding as well as managing the complex constraints operating at the site). In addition, use of the planning tools reduced the number of interfaces between dissimilar materials/technologies allowing improved **quality control** on site, and improved **product quality** arising from the maximisation of finished assemblies under factory controlled conditions [7].

A planning expert and Vice President of WEN Qatar W.L.L. gave the following testimonial: *“Managing the numerous constraints posed by us internally and by our interface with other stakeholders is an extremely complex and challenging issue. We have identified the theories and*

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concepts for multi-constraint management developed by CCIR researchers and are currently using them on most of our projects. We found these concepts extremely effective and they **contributed to increase the efficiency of our projects' delivery**; decrease wastages on site, and integrate our operation with our projects' partners. There are among the first and fewest concepts in Project Management to provide a holistic and integrated management of the multiple constraints involved in projects" [8].

5. Sources to corroborate the impact

- [1] [NE Business web site](#)
- [2] Testimonial from a Senior Manager from Dealim Industrial
- [3] Final Report of the Knowledge Transfer Partnership
- [4] Testimonial from the Managing Director of Datum360 Ltd.
- [5] [NE Business web site](#)
- [6] [Faithful and Gould Website](#)
- [7] Testimonial from the MD of Deepdale solutions Ltd.
- [8] Factual statement from WEN Qatar W.L.L.