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EDITORIAL

Festschrift honouring Dr. Glenn Ballard

Introduction: the enigma of Dr. Glenn Ballard

This Festschrift honours the seminal achievements of Dr. Glenn Ballard in academia and in construction practice. As an academic, Glenn is one of the most influential scholars in construction management, both a prolific writer and highly cited. As a practitioner, he has had enormous influence: management methods that he pioneered are in everyday use in construction projects throughout the world. Indeed, Glenn's achievements are so significant that it is difficult to pinpoint any other person with greater influence on the theory and practice of construction management.

Yet Glenn presents us with an enigma. We see few, if any, of the usual antecedents for an influential and impactful career in construction management: he has no formal education in construction management; he has not held a tenured position at a university; he has not had access to generous research funding; he has not held any influential position in a big organisation in which he might have trialled new ideas; and he has neither collected nor analysed large sets of empirical data.

How, then, has he been able to gain insight and have a significant impact in academia and industry? First, instead of formal education in construction management, he gained first-hand experience and understanding of construction as a field worker on site and then breaking through to managerial positions[1]. Second, instead of gaining formal academic standing, he has collaborated with both industry- and academic peers and with numerous students to amplify intellectual efforts. Third, instead of relying on academic funding, he excelled at working with individuals and companies to carry out research in the field. Fourth, instead of influence within an organisation, he has turned to community building, both in research and in industry. Fifth, instead of seeing research as only data collection and analysis, his research is characterised by identifying and actively solving problems encountered in practice.

The desire to celebrate Glenn's accomplishments and honour his influence on our own work and that of so many others, came in anticipation of his 75th birthday celebration. As "plans are forecasts and forecasts are always wrong"—one of many of Glenn's apt characterisations of the state of affairs—the Covid pandemic derailed our plan, and it is only now coming to realisation with this Festschrift. We start with a short biography.

Short biography

Herman Glenn Ballard was born in 1946 in Texas and raised there. He has a BA in Liberal Arts in Mathematics from St. John's College, Santa Fe, New Mexico, granted in 1968, an MA in Philosophy from the University of California, Davis, California, granted in 1977, and an MBA from Holy Names College, Oakland, California, granted in 1985. He earned a PhD degree in Civil Engineering in 2000 at the University of Birmingham, UK.

"Glenn entered the construction industry as a pipefitter's helper, transitioned to construction engineering, and in 1980 was named Manager of Productivity Improvement for a construction division of Brown and Root. He subsequently became an internal management consultant with Bechtel, working on all aspects of project delivery and supporting projects in other Bechtel divisions such as the South Texas Nuclear Plant" (LIPS 2019).

Glenn is a "maker" at heart. He deeply enjoys the act of building, with the creativity it demands to envision, design, plan, and execute the work, whether it is using physical parts or ideas. He can get really angry when this act is trivialised. Starting his career in construction as a field worker, he learned the skills of the trade but soon came to realise that the builder's success is hampered by externalities such as lack of information, materials, and space for work. In addition, he noted that crew-level planning was missing from the managerial planning process (Ballard 1981). The Last Planner® System[2] (LPS) (Ballard 1994, 2000c) emerged from the identification of this gap.

Throughout the 1980s and later, his work focussed on filling this gap. He began a management consulting business in 1987. As a productivity improvement consultant, Glenn and his long-standing collaborator Greg Howell rescued many failed projects (e.g., Ballard *et al*. 1996), and in the process articulated the theoretical underpinning of the LPS. At the same time, Glenn gained a toehold in the academic community, through involvement with the Construction Business Roundtable (Ballard 1981) and subsequently the Construction Industry Institute (CII) at the University of Texas, Austin, through Greg's ties with Stanford University and Greg's teaching at the University of New Mexico, and with his appointment in 1989 as a Lecturer in the Department of Civil and Environmental Engineering at the University of California, Berkeley (UC Berkeley) to teach a graduate-level class on Productivity Improvement.

Glenn gradually transitioned from industry to academia by earning his PhD (Ballard 2000c), which consolidated his ideas for the LPS. He was appointed at UC Berkeley as an Associate Adjunct Professor (2004-2019) and became the Research Director of UC Berkeley's Project Production Systems Laboratory (P2SL) in 2005. Glenn retired from his position as Research Director in 2019 but continues in a support role as a Research Associate for P2SL to this date. At various times, Glenn also held academic positions at Stanford University, Loughborough University, Nottingham Trent University, and the Norwegian University of Science and Technology (NTNU).

Key collaborators

Glenn's first and foremost collaborator was Greg Howell. They met in 1979 on a failing project where Greg was called in as a consultant and a volunteer in the project was identified to help him with the rescue effort. Greg turned down the first person who had been volunteered to help and insisted that someone be assigned who could really help; that was Glenn, a kindred spirit. Glenn's obituary to Greg Howell, who passed away in 2020, stated that that meeting "began a lifelong intellectual partnership, each learning with and from the other" (Ballard 2020a). Glenn aptly described their collaboration (Ballard 2020a):

> Greg and Glenn began a long career of working together, both in consulting and in construction management research. These tended to intertwine, with practice spurring development of explanatory theory and application of theory spurring further improvement in practice.

Glenn and Greg collaborated for many years on the development of the LPS (e.g., Ballard 1994, Ballard and Howell 1994, 1998b, Howell and Ballard 1994). Their joint efforts also covered construction management theory (Ballard and Howell 2003), safety in construction (Howell *et al*. 2002), production system design and work structuring (Ballard *et al*. 2001a), and many more topics. In 1997, they formed the Lean Construction Institute to disseminate their ideas and engage with the industry more widely.

Glenn met Lauri Koskela in 1991. At the time, Lauri was a visiting scholar at Stanford. He had been studying the transformation and flow perspectives on production and recognised the need to combine them into a holistic theoretical framework to spur new thinking on project delivery in the construction industry (Koskela 1992). This meeting was the start of a longstanding research collaboration. Their joint work has especially addressed design management (Koskela *et al*. 1997; Ballard and Koskela 2009, Ballard and Koskela 2013), the relation between management and production (Koskela and Ballard 2012), as well as theory and methods of production management (Ballard *et al*. 2001). Furthermore, the underlying theories of the LPS have been a long-standing focus in Lauri's work (Koskela 2000, Koskela and Ballard 2006).

Glenn has had a wide-ranging and enduring collaboration with Iris D. Tommelein, also at UC Berkeley. Glenn's entrée into more extensive academic study came through his work on a research project for CII that focussed on uncertainty in the piping function (Howell and Ballard 1995). That report, critical of accepted construction management practices at the time, became the topic of many conversations with Iris, from the moment she had joined the faculty at UC Berkeley in 1996. The year prior, she had spent a year chasing pipe and steel on an oil refinery project in Texas, and Glenn's LPS concept struck the perfect chord (Tommelein 1998, 2015) and led to a deep, long-term collaboration. Their joint work has addressed topics like organisation of construction management (Tommelein and Ballard 1997a, 1997b), computer support for production management (Choo *et al*. 1999), and the LPS (Ballard and Tommelein 2021).

The research of Glenn and Iris' first PhD student, Hyun Jeong (James) Choo, was conducted in collaboration with Todd Zabelle. Todd at the time was in the roofing contracting business but using computer-based 3D design, conducting operations analyses, and experimenting onsite with deployment of the LPS; ongoing efforts with Glenn that were cited in the Egan Report (Egan 1998, p. 23). James' PC-based implementation of the LPS (Choo *et al*. 1999) morphed several years later into a full-fledged web-based implementation of the LPS to manage the civil works on the Heathrow Terminal 5 project.

In addition, among Glenn's industrial research collaborators are Paul Reiser (Ballard and Reiser 2004), Peter H. Morris (Ballard and Morris 2010), and Ari Pennanen and Yrjänä Haahtela (Pennanen *et al*. 2011), to name but a few.

Glenn also has long term collaborations with many academics from different parts of the world, including Christine Pasquire (UK), Luis Fernando Alarcon (Chile), Carlos T. Formoso (Brazil), Tariq Abdelhamid (USA), and Fritz Gehbauer (Germany), to name but a few. Such collaborations involved Glenn's participation in keynote presentations in academic conferences and seminars for the industry, joint papers, or simply informal discussions with researchers.

Another large group of collaborators is made up of students advised and some formally co-supervised by Glenn. Among these are numerous UC Berkeley graduate students and PhD students in many universities in countries around the world, a number of whom presumably had no formal arrangement for supervision by Glenn. He once told one of us that he reserves time in his calendar for advising students from other universities who approach him with questions related to lean construction. It has not been unusual for exchanges of ideas with students to continue long after their graduation, as was

the case for example with Luis F. Alarcón (Salazar *et al*. 2018), Roberto J. Arbulu (Arbulu and Ballard 2004, Ballard and Arbulu 2004), Jan A. Elfving (Elfving *et al*. 2005), and Olli Seppänen (Seppänen *et al*. 2010), again, to name but a few. Thus, through a very wide range of collaborations, Glenn has not only greatly amplified his own efforts, but also inspired and nurtured many others.

Contributions to knowledge and practice

Glenn's contributions include practical, theoretical, and strategic aspects. He derived new practices based on theoretical observations, and new theories based on practical implementations. His theoretical and practical contributions, realised on his own and with his numerous collaborators, especially Greg Howell, accumulated to have a strategic impact on the construction industry.

Last Planner® System (LPS)

Over the course of more than 30 years, Glenn has been developing and extending the Last Planner® System (LPS) (Ballard 2000c). The LPS is articulated by means of a set of planning functions, principles, processes, and methods. In keeping with Glenn's relentless desire for continuous improvement, recognising the limits of one's knowledge, the LPS is described as a Benchmark to meet and beat (Ballard and Tommelein 2016, 2021). As described in the 2020 Benchmark (Ballard and Tommelein 2021), the LPS

> was initially designed as a system for planning and controlling production on projects, that is, to do what is necessary to achieve set targets. It was understood to differ from project controls, which sets targets (objectives and constraints on their delivery) and monitors progress toward them.
>
> Initially, LPS consisted only of lookahead planning (Ballard 1997), weekly work planning, and learning from breakdowns. In the early 2000s, planning and scheduling project phases (which provide inputs to lookahead planning) were added to its scope [...]. This 2020 Current Process Benchmark further extends LPS in principle to both production[3] (i.e., striving for targets) and project planning and control (i.e., setting targets).

Relational contracting

Questioning how commercial terms should be structured to enable more collaborative practices and lean project delivery, Glenn and Greg explored alternative contract forms, design-build, alliancing, the UK's New Engineering Contract, and other contracting practices. In 2004, they organised a symposium on relational contracting (Ballard and Howell 2005).

In collaboration with Sutter Health, a northern California Healthcare provider keen to become the 'owner of choice' for designers and builders, they identified the need for a new type of relational contract. Sutter's legal counsel, Will Lichtig, took on the challenge and wrote the Integrated Form of Agreement (IFOA) (Lichtig 2006). These seminal initiatives made a strong contribution to the development and adoption of the concept of Integrated Project Delivery (IPD).

Target Value Design

Questioning how cost management should inform integrated product and process design, resulted in extensive research into Target Value Design (aka. Target Value Delivery), where rapid cost estimating supports design decision-making all along, rather than cost being estimated when design nears completion (Tommelein and Ballard 2016, Ballard 2020b). In lean construction, Target Value Design has strategic significance: it is the first lean approach through which clients can capture a fair share of the savings achieved through lean, and in consequence, it leads to a situation where clients actively promote lean implementation in their projects.

Lean Project Delivery System

Questioning the limitations that stem from viewing construction isolated from what is upstream and downstream of it, Glenn articulated the Lean Project Delivery System (LPDS) (Ballard 1999b, Ballard 2008). The LPDS is a prescriptive framework for processes and practices for managing all phases of a project, namely Project Definition, Lean Design, Lean Supply, Lean Assembly, and Use. They are supported by work structuring and production control (the LPS), with learning loops throughout.

Construction as flow

From the outset, Glenn understood and applied the concepts of the flow of drawings (information), materials, and resources in construction (Ballard 1981, Ballard and Howell 1994). He built on the theoretical foundation of Koskela's TFV theory (Koskela 1992, 2000), providing insights into practical application of the flow concept to improve workflow and realised the tension it provokes with practices such as Earned Value Management (Ballard 1999a, Kim and Ballard 2000). This body of work influenced Sven Bertelsen *et al*.'s development of the ideas of critical flow (Bertelsen *et al*. 2006) and Rafael Sacks' exploration of the conditions for good production flow in construction (Sacks 2016).

Work structuring

Questioning of the prevailing conceptualisation of how work should be broken down in pieces (e.g., work breakdown structures), informed by the newly found focus on production system design (including product and process

integration, and the LPDS) (Ballard *et al*. 2001) led Glenn and colleagues to develop the concept of work structuring (Ballard 1999b, Tsao *et al*. 2004).

As the methods for the LPS became better articulated over time, it also became clear that the LPS is agnostics about work structuring. More definition could be given to workflow and new methods devised to shape it (e.g., Ballard *et al*. 2003). This spurred experimentation with takt planning (Frandson *et al*. 2013, Linnik *et al*. 2013), an area of research that has since grown significantly with experiments and implementation underway on projects around the world.

Engineered-to-order prefabricated building systems

Glenn explored the problem of integrating the management of different production units involved in construction projects, especially engineered-to-order (ETO) prefabricated building systems. In these systems, the customer order is delivered at the design phase. He made several contributions related to the use of pull production as a mechanism to deal with uncertainty in site assembly, control of work in progress (WIP), and the effectiveness of communication between construction sites and suppliers (Ballard *et al*. 2003, Ballard and Arbulu 2004, Elfving *et al*. 2004, Ballard and Tommelein 2012).

Design management

Glenn's many papers on design management have been highly influential in the lean construction community. These have covered topics such as the nature of the construction design process, project definition, managing design workflow, and set based design (Ballard & Koskela 1998; Ballard 2002; Whelton and Ballard 2002).

First Run Studies

A First Run Study consists of a detailed plan produced by a team of people who will perform a set of operations for the first time. This plan is put into practice in the first run and is followed by an assessment, which may lead to the redesign and retrial of the operations until a satisfactory standard is met (Ballard 2000a). A First Run Study is a process prototype that involves understanding the necessary work, skills and resources, and the interactions with other operations (Hamzeh *et al*. 2012). This very practical contribution was certainly inspired by Glenn's experience as a builder.

Community building

International Group for Lean Construction (IGLC)

The origin of the International Group for Lean Construction can be traced back to a discussion between Glenn and Lauri at Stanford University in late summer of 1992. Lauri was due to return to Finland from his 1-year stint there as a visiting researcher. Glenn asked what would happen to the topics Lauri was researching, and Lauri responded by suggesting that leading universities would probably organise conferences to look further into them.

In the following winter, Glenn returned to this discussion and insisted that Lauri should start preparations for a workshop. This he did, and in August 1993, a small workshop with a dozen participants, was held in Espoo, Finland. Most importantly, Luis F. Alarcon volunteered to organise a similar workshop the following year in Chile. Luis later also edited the first 3 years' proceedings (Alarcón 1997). The conference series, which came to be called the International Group for Lean Construction (IGLC, iglc.net), was thus launched. Since then, an IGLC conference has been held annually. All IGLC papers, a total of 1879 to date, are peer-reviewed and are available with open access on the IGLC website.

The organisation of the group is lean: at the end of each conference, a business meeting is held where everybody present can take part. A central task for the business meeting is to decide the venue and organisers of the next conference. Over time, with larger conferences and more running matters, the Charter of IGLC was compiled and ratified in 2012. According to the Charter, IGLC has a General Secretary and other functionaries, all volunteers. Membership is free but contingent on participation in the annual conference, and the business meeting remains the sole decision-making authority.

Over the years, IGLC has provided the lean construction community—always including academics as well as practitioners—a premium venue for presenting papers and discussing new ideas, and the conferences have been the crucible of much innovative thinking. All this has been instrumental for broad academic and industrial diffusion of the ideas developed and promoted by the lean construction community.

Both from the outset and subsequently, Glenn has been closely involved in the operations of IGLC in many ways. As of the 2021 conference, he has authored or co-authored 111 IGLC papers. He has participated as a reviewer, session chair, conference technical chair, offered his comments on papers in the sessions, and advised numerous researchers during the sessions, the social interludes, and the IGLC Summer School for PhD students. Without Glenn's strategic eye, initiative, and commitment, the IGLC might not exist as we know it.

Lean Construction Institute (LCI)

Glenn and Greg felt that this new understanding of production in construction, the body of knowledge of lean construction being articulated by the IGLC community, needed to be taught widely and to more practitioners. They founded the Lean Construction Institute (https://leanconstruction.org/) in 1997 to that effect and they started to offer training workshops around the country on the LPS with hands-on simulations such as the Parade of Trades (Tommelein *et al*. 1999c). To extend LCI's reach, Glenn and collaborators wrote a number of white papers that sharpened and conveyed his thoughts on lean construction, and with Iris he developed workbooks to help teach the LPS (Tommelein *et al*. 1999a, 1999b).

LCI's efforts in raising awareness of the possibilities of working differently based on a lean operating system fuelled the demand from industry for training and consulting. It also became clear that more research needed to be done to further advance lean understanding and adoption across the board in the architecture, engineering, and construction industry. The industry needed (and still needs) help in overcoming deeply-entrenched received traditions.

In 2004, Glenn and Greg launched Lean Construction Journal, with LCI as the publisher (Abdelhamid and Mossman 2004). This is an international refereed, open access journal devoted to lean construction practice and research (https://leanconstruction.org/pages/learning/publications/lean-construction-journal/).

LCI has turned out to be a very important forum for exchanging notes and accessing the existing knowledge base by practitioners and companies implementing lean construction. It now has 30 communities of practice all over the US. Along with the success of LCI, corresponding institutes or similar associations have been established in many other countries.

Project Production System Laboratory (P2SL)

In the State of California, acute healthcare facilities are a key infrastructure: they must remain fully functional after a major earthquake. The State therefore mandated stringent building regulations enforced by its Office of Statewide Health Planning and Development (OSHPD). The OSHPD approval process of design documents prior to construction was taking a long time. Thinking that submitting documents earlier would result in earlier approvals, design firms ended up sending in poorly coordinated work, thereby increasing the workload imposed on OSHPD, adding backcheck cycles, and further increasing the time to approval. This downward performance spiral had to be broken, but no single company could do so.

This systemic challenge defined the founding by Glenn and Iris of the Project Production Systems Laboratory (P2SL, https://p2sl.berkeley.edu/) at UC Berkeley in 2005. In 2006, Paul Reiser from Boldt graciously offered space for P2SL to host 5 days (spread out over a few weeks) to value-stream map the process of design-to-delivery-to-OSHPD of a 100-bed hospital. Numerous healthcare providers, design firms, contractors, and indeed also OSHPD personnel participated in the exercise, thus opening lines of communication that would help the community reverse the trend.

P2SL is dedicated to developing and deploying knowledge and tools for the management of project production systems and the management of organisations that produce and deliver goods and services through such systems. P2SL's mission is to understand through experimentation how to effectively design, execute, and systematically improve the performance of project production systems. P2SL students and researchers work with industry partners, pursuing the objective of functioning as a learning laboratory as the industry embraces lean production and the challenge of adapting its concepts and techniques to the Architecture-Engineering-Construction (AEC) domain.

Lean Design Forum

P2SL embraces the scope defined by the LPDS. A key part is design. To foster ideas around lean as it applies to design, Glenn launched P2SL's Lean Design Forum in late 2006. The forum was received enthusiastically by architects, engineering design specialists, and others keen to improve lean project delivery, who wanted to share ideas and improve their practices about, among other topics: architectural programming, collaborative design, evidence-based design, design for safety, agile methods, language-action, moods, creativity, innovation, decision-making, set-based design, knowledge management, computational design, and disruptive technologies. The Lean Design Forum has since taken place more-or-less twice a year, with P2SL hosting the event early in the year in the San Francisco Bay Area, and LCI hosting it mid-year in the Midwest or East Coast of the US.

Lean in the Public Sector (LIPS) forum

Legislative constraints on public tendering pose specific challenges to implementation of lean in public construction and infrastructure projects. Questioning such limitations encountered by public owners in their ability to adopt lean practices, Michael Bade from the University of California San Francisco petitioned the California legislature to allow best-value procurement (Bade and Haas 2015). This was a key step in launching a forum around lean in the public sector construction.

Glenn initiated the Lean in the Public Sector (LIPS) forum (http://leaninpublicsector.org/) with P2SL hosting it in 2008 and 2009. Subsequently, the event has rotated around the world: Finland, Germany, Australia, United

Kingdom, Spain, Denmark, Chile, India, and Qatar, with Glenn continuing to be the driving force behind LIPS (A. Abdel-Azim, personal communication with Lauri Koskela, 19 Jan 2021).

Glenn's role in the evolution of lean construction

Glenn's contributions have been essential for the considerable evolution of the knowledge base and the penetration of lean construction. Much has happened in the thirty years of active development of lean construction (for a description of the state-of-the-art, see Tzortzopoulos *et al*. 2020). While the starting point was short term planning on site, the coverage of lean has extended to all time frames, and to all other stages of a construction project, especially design, and further beyond a project, to the supply chain. Further, the scope of lean construction has widened from production to organisational and contractual issues. Cost management has evolved, from a support function to an important discipline collaborating with other disciplines on equal footing. New collaborative decision-making tools (especially Choosing by Advantages) have been adopted (Arroyo *et al*. 2012, 2015). The synergy between lean and digital technologies is increasingly being explored and exploited, especially in relation to Building Information Modelling (Sacks *et al*. 2010). The underlying theories of lean have been unveiled (Koskela 2020). Along with the stabilisation of construction processes through lean construction, it has been possible to progressively adapt concepts and methods originally developed in the Toyota Production System (Liker 2003) and to learn from other service sector industries such as healthcare. Briefly, the lean construction knowledge base has been extended, deepened and connected to cognate knowledge bases.

Along with the evolution of the concepts of lean construction, practical application of lean construction methods has grown dramatically, and lean practices are developed and improved increasingly by industrial stakeholders. Glenn's practical contributions, especially the LPS, have played a paramount role. LPS has become best practice in many countries for managing project production, introducing a systematic approach for lookahead- and commitment planning and control (Olivieri *et al*. 2019). LPS has started to make inroads even into other industries, such as shipbuilding (Emblemsvåg 2014). Furthermore, Target Value Design has proved to offer major benefits to clients in terms of cost reduction as well as cost certainty, and its use has grown rapidly. Other practical contributions that can be attributed to Glenn include Work Structuring and First Run Studies.

Glenn's theoretical contributions have been closely related to his practical contributions in construction and design management. He has presented seminal insights into the role of uncertainty and buffers in construction production (Howell *et al*. 1993). In turn, his exploration of design iteration straddles the flow and the value generation understanding of design (Ballard 2000b). The work on the nature of construction as production (Ballard and Howell 1998a) has provided an explanation of the peculiar characteristics of construction from the lean viewpoint. Further, Glenn has numerous studies addressing the theoretical aspects of cost management in construction (Ballard and Reiser 2004, Ballard 2012, Ballard and Rybkowski 2009).

But beyond theoretical and practical contributions, Glenn has made strategic contributions – contributions that have significantly changed the course of events, beyond their immediate context. As he wrote, together with Greg (Howell and Ballard 1998): "Companies beginning to implement lean report an unexpected phenomenon; each change creates the opportunity for more and often larger improvements." Glenn's community building effort, as described, represents intentional and highly successful strategic action. By creating institutions (such as IGLC and the LCI) and forums for debate (such as the IGLC and LCI conference series and P2SL's events), Glenn has brought individuals, companies and knowledge together with synergistic impacts, in both practice and research. These institutions have turned out to be sustainable and successful. It is noteworthy that he has supported the formation of lean construction institutes also in other countries. Finally, Glenn has actively supported the building of individual and organisational competence in lean construction. This has occurred in the framework of formal and informal supervision of PhD students, consulting, and generous support to all who have asked for his advice, and the number of academics involved in lean construction research and teaching has grown considerably. The competences created have led to further development and diffusion of lean construction.

Future of lean construction

What, then, can be said about the future of lean construction, especially as an academic topic? Predicting the future is notoriously difficult, and we restrict ourselves to a few salient points.

A first point is that many current trends and concerns will continue, although with increased intensity and evolving focus. For example, further success of industrialised construction will require support through lean principles and methods. The attention to large, complex projects, including mega-projects, will certainly be sustained. While at the outset of lean construction the attitude to computing was cautious ("first root out waste before you automate to add value"), digital design and engineering including AI processing of big data, shared data models, and cloud computing, are revolutionising how we work. Digital Twin Construction (DTC), for example, is a new conceptual model for managing

production in construction that applies the lean PDCA cycle and leverages the data streaming from a variety of site monitoring technologies and artificially intelligent functions to provide accurate status information and to proactively empower people to optimise ongoing design, planning, and production (Sacks *et al*. 2020). The work on the underlying theory of lean construction will surely continue.

A second point is that there is now an unprecedented social demand for lean construction and lean in general, in the form of the overwhelming evidence for the need for rapid and major decrease of greenhouse gas emissions. More efficient processes, and their continuous improvement, are required, and lean principles and methods need to be used in many ways. This brings to the fore the need for explicit, teachable theories as well as dissemination of knowledge for practical use.

A third point is that lean construction, in so far as it is founded on theories of production, stands in serious contradiction to several influential neighbouring disciplines, such as economics, organisational theory and management. The idea, embodied in lean construction, that our understanding of production importantly determines how to economise, organise, or manage, is profoundly alien to these disciplines, and threatens to undermine existing paradigms (Koskela 2017). The situation where these disciplines ignore lean, even subscribing to theories which contradict lean principles, is most counterproductive. Interdisciplinary engagement and discussion are needed.

Contents of the Festschrift

This Festschrift contains nine papers that extend Glenn's academic and practical contributions. These papers add to the already wide literature on lean construction in archival journals and in the conference paper repository of the IGLC.

The first four papers discuss topics related to Glenn's key contributions to construction management practice. Daniela Viana, Carlos Formoso, and Fernanda Bataglin, in their paper "Requirements for developing production planning and control systems for Engineer-To-Order Industrialised building systems," propose a set of core requirements for production planning and control systems used in the context of industrialised building systems procured in the Engineer-to-Order mode. The LPS was one of the starting points for this development, along with production control models from manufacturing. Chuanni He, Min Liu, Thais da C.L. Alves, Natalie Scala, and Simon Hsiang, in their paper "Prioritizing collaborative scheduling practices based on their Impact on project performance," explore how different collaborative practices should be used for the best effects in the context of collaborative scheduling, such as in the case of the LPS. An innovative method based on information theory was used for analysing the survey data.

Next, Kristen Parrish, Zofia Rybkowski and Paz Arroyo, in their paper "Assessment of current Target Value Design practices: consistencies and inconsistencies of application," identify key practices of Target Value Design, a method championed by Glenn. The authors found inconsistencies in its application that may account for the variation in the outcomes of the use of this method. Cecilia Gravina da Rocha, Samuel Korb and Rafael Sacks, in their paper "Work structuring and product design for customised repetitive projects," argue that in customised repetitive projects, a trade-off between flow and value is needed. They applied Glenn's concept of work structuring for production planning in construction and identified and evaluated five distinct production system designs to solve the trade-off problem between flow and value.

The next two papers refer, inter alia, to Glenn's efforts to diffuse lean construction. Jan Elfving, in his paper "A decade of lessons learned: deployment of lean at a large general contractor," describes longitudinally the process of piloting and implementing elements of lean construction in a large construction company. In turn, Jordar Lohne and his 21 co-authors, in their paper "The emergence of lean construction in the Norwegian AEC industry," provide a narrative-based qualitative analysis of the emergence and impact of lean construction on a national level, notably in the Norwegian AEC industry. Glenn's leadership among all promoters of lean construction is found to have been crucial.

Two papers address the interface and interaction of the technical and the social, a topic in which Glenn has shown keen interest. Petteri Uusitalo, Eelon Lappalainen, Olli Seppänen, Ergo Pikas, Antti Peltokorpi, Nikolai Menzhinskii and Mikko Piitulainen, in their paper "To trust or not to trust: is trust a prerequisite for solving design quality problems?," present and validate a conceptual framework for building design management and trust in a project context. Nuno Gil, in his paper "Megaprojects: a meandering journey towards a theory of purpose, value creation and value distribution," describes his research trajectory, which started from lean construction research as a PhD student co-supervised by Glenn. He then switched to social science-based analysis of mega-projects. He presents his conceptual model of megaprojects, based on Ostrom's theory on the governance of common-pool resources. However, in the conclusion of the paper, he unexpectedly finds common ground with lean construction, especially the LPS.

In the last contribution to the Festschrift, Ergo Pikas, Lauri Koskela, and Olli Seppänen, in their paper "Causality and interpretation: a new design model inspired by the Aristotelian legacy," build on Glenn's views on the role of rhetoric in design. They present a

new design model, covering the integrated design process structure for technical and social design activities.

Concluding words

We intended to publish this Festschrift on the occasion of Glenn's 75th birthday. However, the COVID pandemic impacted the paper solicitation, writing, and review process. Furthermore, towards the end of the editing period, the world, and our understanding of it, dramatically changed once more: on 24 February 2022, Russia invaded Ukraine, leading to rigorous countermeasures, especially economic, by several countries. This tragic war also overshadowed the publication, on 28 February, of an important new report of the Intergovernmental Panel on Climate Change (IPCC 2022), arguing that the time window for avoiding irreversible climate changes is very narrow.

In situations where urgent action is required against a backdrop of great uncertainties, people often feel powerless and unable to act. This occurs also in the context of construction, where uncertainty of the ends and means is rife, and people are sometimes at a loss as to what to do. Glenn guides us here (Ballard *et al*. 2007):

> ….no one is a helpless victim of fate. […] Everyone can pursue the lean ideal[4]. Everyone can apply lean principles and methods to their own processes. Everyone can invite their customers, suppliers and partners to join them on the lean journey.

Effective and efficient action is needed to encounter the changes and challenges facing us. Lean can be applied to guide towards such action. However, this is not enough. The life achievements of Glenn illustrate the significance of working as individuals and as a community towards the common good. By his example, Glenn continues to show that we all have the choice to shape our lives and to be a force for good.

Notes

1. In academic terms, this is called unique adequacy (Rooke and Kagioglou 2007).
2. Last Planner®, Last Planner System®, LP®, and LPS® are registered trademarks of the Lean Construction Institute (LCI) (www.leanconstruction.org).
3. Production spans designing as well as making, i.e. design and construction.
4. The Lean Ideal is to provide a custom product exactly fit for purpose delivered instantly with no waste (*Ballard et al*. 2007).

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References

Abdelhamid, T., and Mossman, A., 2004. Editors' note. *Lean construction journal*, 1 (1), i–iii. https://leanconstruction.org/uploads/wp/media/docs/lcj/V1_N1/LCJ_04_0000.pdf [Accessed 1 May 2022]

Alarcón, L., ed., 1997. *Lean construction*. Rotterdam, The Netherlands: CRC Press.

Arbulu, R. and Ballard, G., 2004. Lean supply systems in construction. *In*: *Proceedings of the 12th Annual Conference of the International Group for Lean Construction (IGLC12)*, Helsingør, Denmark, 3–5 August, 1–13.

Arroyo, P., Tommelein, I., and Ballard, G., 2012. Deciding a sustainable alternative by 'Choosing By Advantages' in the AEC industry. *In*: Proceedings of 20th *Annual Conference* of the International Group for Lean Construction (IGLC20), San Diego, CA, 41–50.

Arroyo, P., Tommelein, I.D., and Ballard, G., 2015. Comparing AHP and CBA as decision methods to resolve the choosing problem in detailed design. *Journal of construction engineering and management*, 141 (1), 04014063.

Bade, M., and Haas, C., 2015. Using lean design and construction to get more from capital projects. *Government finance review*, 31 (2), 39–44.

Ballard, G. 1997. Lookahead planning. *In*: *Proceedings of 5th Annual Conference of the International Group for Lean Construction (IGLC5)*, Griffith University, Gold Coast, Australia, July.

Ballard, G., 1981. Crew level planning. *In*: *1981 Conference on Construction Productivity Improvement*, 15–16 September, University of Texas, Austin, 133–144, Reprinted: Ballard, G., 2015. Crew level planning. *Lean construction journal*, 15–24. www.leanconstructionjournal.org

Ballard, G., 1994. *The last planner*. Monterey, CA: Northern California Construction Institute, 22–24.

Ballard, G., 1999a. Improving work flow reliability. *In*: *Proceedings of 7th Annual Conference of the International Group for Lean Construction*, Berkeley, CA, 26–28 July, 275–286.

Ballard, G., 1999b. *Work structuring*. LCI White Paper No. 5, June. https://p2sl.berkeley.edu/white-papers/.

Ballard, G., 2000a. *Lean project delivery system*. LCI White Paper No. 8, September 23, revision 1, https://p2sl.berkeley.edu/white-papers/.

Ballard, G., 2000b. Positive vs negative iteration in design. *In: Proceedings Eighth Annual Conference of the International Group for Lean Construction*, IGLC-6, Brighton, UK, 17–19.

Ballard, G., 2000c. The Last Planner System of production control. Doctoral dissertation, University of Birmingham.

Ballard, G., 2002. Managing work flow on design projects: a case study. *Engineering, construction and architectural management*, 9 (3), 284–291.

Ballard, G., 2008. The lean project delivery system: an update. *Lean construction journal*, 2008, 1–19. https://leanconstruction.org/

uploads/wp/media/library/id53/The_Lean_Project_Delivery_System_An_Update.pdforhttps://leanconstruction.org/pages/learning/publications/lean-construction-journal/lcj-back-issues/2008-issue/

Ballard, G., 2012. Should Project budgets be based on worth or cost. *In: Proceedings of 20th Annual Conference of the International Group for Lean Construction*, San Diego, CA, 761–770.

Ballard, G., 2020a. In memoriam: Gregory Alvin Howell. *Journal of construction engineering and management*, 146 (10).

Ballard, G., 2020b. Target value delivery. In: P. Tzortzopoulos, M. Kagioglou, and L. Koskela, eds. *Lean construction: core concepts and new frontiers*. Abingdon, UK: Routledge, 148–161.

Ballard, G. and Arbulu, R., 2004. Making prefabrication lean. *In:* Proceedings of *12th Annual Conference of the International Group for Lean Construction*, 3–5 Aug 2004. Helsingør, Denmark.

Ballard, G., Carsten, M., and Howell, G. 1996. PARC: a case study. *In: Proceedings of 4th Annual Conference of the International Group for Lean Construction*, Birmingham, UK, 14 p.

Ballard, G. and Howell, G., 1994. Implementing lean construction: stabilizing work flow. *In*: *Proceedings of 2nd International Group for Lean Construction Conference*, Santiago, Chile, in Alarcon, L. (ed.)(1997) *Lean construction*, The Netherlands: AA Balkema.

Ballard, G. and Howell, G., 1998a. What kind of production is construction. *In*: *Proceedings of 6th Annual Conferene International Group for Lean Construction*. Guarujá, Brazil, 13–15 Aug 1998.

Ballard, G., and Howell, G., 1998b. Shielding production: essential step in production control. *Journal of construction engineering and management*, 124 (1), 11–17.

Ballard, G. and Howell, G.A., 2003. Competing construction management paradigms. *In*: Construction research congress: wind of change: integration and innovation, Honolulu, Hawaii, 1–8.

Ballard, G., and Howell, G.A., 2005. Relational contracting and lean construction. *Lean construction journal*, 2 (1), 1–4.

Ballard, G., *et al.*, 2007. *Road map for lean implementation at the project level*. The Construction Industry Institute, Research Report 234–11. Austin, Texas.

Ballard, G. & Koskela, L. 1998. On the agenda of design management research. *In*: *Proceedings of 6th Annual Conference of the International Group for Lean Construction*, 13–15 Aug 1998. Guarujá, Brazil.

Ballard, G. and Koskela, L. 2009. Design is a Physical Process, Too. In: *DS 58-2: proceedings of ICED 09, the 17th international conference on engineering design, vol. 2, design theory and research methodology*, 24–27 August 2009. Palo Alto, CA, 251–262.

Ballard, G. and Koskela, L., 2013. Rhetoric and design. *In*: *DS 75-2: proceedings of 19th international conference on engineering design (ICED13), design for harmonies, vol. 2: design theory and research methodology*, 19–22 August 2013. Seoul, Korea.

Ballard, G., Koskela, L., Howell, G. and Zabelle, T., 2001. Production system design in construction. *In:* G. Ballard and D. Chua, eds. Proceedings of 9th Annual *conference of the international group for lean construction,* 6–8 August 2001 Singapore.

Ballard, G., and Morris, P.H., 2010. Maximizing owner value through target value design. *AACE international transactions*, 1 (1), 1–16.

Ballard, G., Harper, N., and Zabelle, T., 2003. Learning to see work flow: application of lean production concepts to precast concrete fabrication. *Journal of engineering, construction and architectural management*, 10 (1), 6–14.

Ballard, G. and Reiser, P., 2004. The St. Olaf College fieldhouse project: a case study in designing to target cost. *In*: *Proceedings of 12th annual conference of the international group for lean construction*, 3–5 August, 234–249. Helsingør, Denmark

Ballard, G. and Rybkowski, Z.K., 2009. Overcoming the hurdle of first cost: Action research in target costing. In: *Construction research congress 2009: building a sustainable future*. Seattle, Washington: ASCE, 1038–1047.

Ballard, G., and Tommelein, I.D., 2012. Lean management methods for complex projects. *Engineering project organization journal*, 2 (1–2), 85–96. 10.1080/21573727.2011.641117.

Ballard, G. and Tommelein, I. D. 2016. Current process benchmark for the last planner system. Online at p2sl.berkeley.edu and reprinted in the *Lean Construction Journal*, 2016, 57–89, www.leanconstruction.org/media/docs/lcj/2016/LCJ_16_011.pdf

Ballard, G. and Tommelein, I.D., 2021. *2020 Current process benchmark for the last planner® system of project planning and control.* Project Production Systems Laboratory, University of California, Berkeley, CA, 111 pp [online]. https://escholarship.org/uc/item/5t90q8q9 and reprinted in the *Lean Construction Journal*, 53–155, https://www.leanconstruction.org/uploads/wp/media/docs/lcj/2021/LCJ_21_001.pdf

Bertelsen, S., Koskela, L., Henrich, G. and Rooke, J., 2006. Critical flow – towards a construction flow theory. *In*: *Proceedings of 14th annual conference of the international group for lean construction (IGLC14)*, Santiago, Chile, 31–32.

Choo, H.J., *et al.*, 1999. WorkPlan: constraint-based database for work package scheduling. *journal of construction engineering and management*, 125 (3), 151–160.

Egan, Sir J. 1998. *Rethinking construction.* https://constructingexcellence.org.uk/wp-content/uploads/2014/10/rethinking_construction_report.pdf

Elfving, J.A., Tommelein, I.D., and Ballard, G. 2004. Improving the delivery process for engineered-to-order products – lessons learned from power distribution equipment. *In*: Proceedings of *12th Annual Conference of the International Group for Lean Construction (IGLC12)*, 3–5 August. Helsingør, Denmark.

Elfving, J.A., Tommelein, I.D., and Ballard, G., 2005. Consequences of competitive bidding in project-based production. *Journal of purchasing and supply management*, 11 (4), 173–181.

Emblemsvåg, J., 2014. Lean project planning in shipbuilding. *Journal of ship production and design*, 30 (02), 79–88.

Frandson, A., Berghede, K., and Tommelein, I., 2013. Takt time planning for construction of exterior cladding. *In*: Proceedings of 21st *annual conference of the international group for lean construction* (IGLC21), Fortaleza, Brazil, 527–536.

Hamzeh, F., Ballard, G., and Tommelein, I.D., 2012. Rethinking look-ahead planning to optimize construction workflow. *Lean construction journal*, 2012, 15–34.

Howell, G., and Ballard, G. 1994. Implementing lean construction: reducing inflow variation. *In*: Proceedings of 2nd *international group for lean construction conference*, Santiago, Chile, in Alarcon, L. (ed.)(1997) Lean construction, AA Balkema, The Netherlands.

Howell, G. and Ballard, G. 1998. Implementing lean construction: understanding and action. *In: 6th Annual conference of the international group for lean construction*, 13–15 August 1998. Guarujá, Brazil.

Howell, G. A., and Ballard, G., 1995. Managing uncertainty in the piping function. Report to Constr. Industry Institute, University of Texas, Austin, TX, November, 103 pp.

Howell, G. A., Ballard, G., Abdelhamid, T. S. and Mitropoulos, P., 2002. Working near the edge: a new approach to construction safety. *In:* Proceedings of 10th *annual conference of the international group for lean construction*, 6–8 August. Gramado, Brazil, 49–60.

Howell, G., Laufer, A., and Ballard, G., 1993. Interaction between subcycles: one key to improved methods. *The journal of construction engineering and management*, 119, 714–728.

IPCC, 2022. Climate change 2022: impacts, adaptation, and vulnerability. *In:* H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama, eds. *Contribution of working group ii to the sixth assessment report of the intergovernmental panel on climate change*. Cambridge: Cambridge University Press.

Kim, Y. and Ballard, G., 2000. Is the earned-value method an enemy of work flow? *In: 8th Annual conference of the international group for lean construction*, 17–19 July 2000. Brighton, UK.
Koskela, L., 1992. *Application of the new production philosophy to construction* (Vol. 72). Stanford: Stanford university.
Koskela, L., 2000. *An exploration towards a production theory and its application to construction*. Espoo, Finland: VTT Technical Research Centre of Finland.
Koskela, L., 2017. Why is management research irrelevant? *Construction management and economics*, 35 (1–2), 4–23.
Koskela, L., 2020. Theory of lean construction. In: P. Tzortzopoulos, M. Kagioglou, and L. Koskela, eds. *Lean construction: core concepts and new frontiers. Lean construction: Core concepts and new frontiers*, Abingdon, UK: Routledge, 3–13.
Koskela, L., and Ballard, G., 2006. What is lean construction–2006. *In: Proceedings of Construction in the XXI Century: local and global challenges-ARTEC*-Rome, Italy.
Koskela, L., and Ballard, G., 2012. Is production outside management? *Building research & information*, 40 (6), 724–737.
Koskela, L., Ballard, G., and Tanhuanpää, V. P., 1997. Towards lean design management. *In: Proceedings of the 5th annual conference of the international group for lean construction,* Gold Coast, Australia, 1–13.
Lichtig, W., 2006. The integrated agreement for lean project delivery. *Construction lawyer*, 26 (3), 1–8.
Liker, J. E., 2003. *The Toyota way*. New York: McGraw-Hill.
Linnik, M., Berghede, K., and Ballard, G., 2013. An experiment in takt time planning applied to non-repetitive work. *In*: Proceedings *of 21st Annual Conference of the International Group for Lean Construction*, 31–2 August. Fortaleza, Brazil, 609–618.
LIPS. 2019. lips2019.com/conference [Accessed 1 May 2022].
Olivieri, H., *et al.*, 2019. Survey comparing critical path method, last planner system, and location-based techniques. *Journal of construction engineering and management*, 145, 04019077.
Pennanen, A., Ballard, G., and Haahtela, Y., 2011. Target costing and designing to targets in construction. *Journal of financial management of property and construction*, 16 (1), 52–63.
Rooke, J.A., and Kagioglou, M., 2007. Criteria for evaluating research: the unique adequacy requirement of methods. *Construction management and economics*, 25 (9), 979–987.
Sacks, R., 2016. What constitutes good production flow in construction? *Construction management and economics*, 34 (9), 641–656.
Sacks, R., *et al.*, 2020. Construction with digital twin information systems. *Data-centric engineering*, 1, 1–26.
Sacks, R., *et al.*, 2010. The interaction of lean and building information modeling in construction. *Journal of construction engineering and management*, 136 (9), 968–980.
Salazar, L.A., Ballard, G., Arroyo, P. and Alarcón, L.F., 2018. Indicators for observing elements of linguistic action perspective in Last Planner® System. *In: Proceedings of 26th annual conference of the international. Group for lean construction (IGLC26)*, Chennai, India, 18–20.
Seppänen, O., Ballard, G., and Pesonen, S., 2010. The combination of last planner system and location-based management system. *Lean construction journal*, 2010, 43–54.
Tommelein, I.D., 1998. Pull-driven scheduling for pipe-spool installation: simulation of lean construction technique. *ASCE, Journal of construction engineering & management*, 124 (4), 279–288.
Tommelein, I.D., 2015. Journey toward Lean Construction: Pursuing a Paradigm Shift in the AEC Industry. *ASCE, Journal of Construction Engineering and Management*, 141 (6), 1–12. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000926.
Tommelein, I. D., and Ballard, G., 2016. *Target value design: introduction, framework, and current benchmark*. Project Production Systems Laboratory, University of California, Berkeley, CA.
Tommelein, I.D., and Ballard, G., 1997a. Coordinating specialists. *In: Proceedings of 2nd international seminar on lean construction*, 20–21 October, Sao Paulo, Brazil, A.S.I. Conte (organizer), also Technical Report 97-8, Construction Engineering and Management Program, Civil and Environmental Engineering Department, University of California, Berkeley, CA. https://doi.org/10.34942/P2G59D.
Tommelein, I.D., and Ballard, G., 1997b. Look-ahead planning: screening and pulling. *In*: *Proceedings of 2nd International Seminar on Lean Construction*, 20-21 October, Sao Paulo, Brazil, A.S.I. Conte (organizer), also Technical Report 97-9, Construction Engineering and Management Program, Civil and Environmental Engineering Department, University of California, Berkeley, CA. https://doi.org/10.34942/P2KW2X.
Tommelein, I. D., *et al.*, 1999a. *The last planner: improving reliability in planning and work flow. T4 workbook version 1.0*. San Francisco, CA: Lean Construction Institute.
Tommelein, I. D., *et al.*, 1999b. *Lookahead planning: streamlining the work flow that supports the last planner. T5 workbook version 1.0*. San Francisco, CA: Lean Construction Institute.
Tommelein, I.D., Riley, D., and Howell, G.A., 1999c. Parade game: impact of work flow variability on trade performance. *ASCE, journal of construction engineering and management*, 125 (5), 304–310.
Tsao, C.C., *et al.*, 2004. Work structuring to achieve integrated product–process design. *Journal of construction engineering and management*, 130 (6), 780–789.
Tzortzopoulos, P., Kagioglou, M. and Koskela, L., eds. 2020. *Lean construction: core concepts and new frontiers*. Abingdon, UK: Routledge, 460 pp.
Whelton, M. and Ballard, G. 2002. Project definition and wicked problems. *In*: *Proceedings of 10th Annual Conference of the International Group for Lean Construction (IGLC10)*, 6–8 August. Gramado, Brazil, 375–387.

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