Construction Research Needs Assessment

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The development of an agenda for construction research is an overwhelming challenge. We can, if we wish, skim the total number of research questions currently underway, focus on individual interests and develop a narrow view of the future. We can also respond to the needs of industry, which bombards us with research needs in journals, in research justification statements, and in business and technical presentations. Their opinion is clear; the future requires that projects be better, faster, cheaper, and safer. There are many research questions, both basic and applied, to be answered in order to make these improvements. Our actions should be guided by this overarching need.

Construction as an academic discipline entails the delivery of the project, and not necessarily just the physical construction of the project. It is important to place construction in its context, as part of a spectrum of activities which make up the delivery process, moving from the conceptual level (needs assessment, feasibility analysis, or concept design) to the detailed level of construction and startup. In fact, it is in the recognition of this continuum that much of current research in information technologies arises based on the vexing fact that data available in earlier stages is often not carried along in a usable format to later stages where it can be of great value. Clearly there is a great deal of work which can be done in the careful coding and transmission of relevant data as packets through the process.

Furthermore, there is much that can be done by applying the tools of one stage in the delivery process to the activities in other stages. For example, the application of process-related measures such as productivity and quality assessment is very common in the construction phase of a project. Such measures are well known and standardized methods are available. However, no such standardized methods exist for evaluating the productivity or quality of the design effort. In a similar vein, the decisions made in one phase can profoundly influence a subsequent phase; hence value engineering and design for constructibility, safety, maintainability and reuse.

If we accept the premise that our research must enable us to build better, faster, cheaper and safer then, we must develop the knowledge needed to design better, faster, cheaper and safer operations. The authors share the conviction that obtaining and using hard data to support the classic steps of record, analyze, devise and implement hold the key. Charts, graphs, tables and ignorance wrapped in the cloak of conventional wisdom will simply not suffice. Questionnaires soliciting subjective and often non-reproducible data will also not suffice. We must develop and learn to use instrumentation to record hard data and thus place our work on a par with colleagues in science and engineering. They have long known that questionnaire based research, no matter how statistically valid, is not the best way to determine the bearing capacity of a soil – you simply have to use the instruments, collect the data and do the analysis.

In the early stages of the project delivery, there is, typically, very little hard data available. In the concept design, bold statistical analyses may be undertaken to assess potential use (for example, population and/or traffic growth, which interestingly are almost notoriously under-predicted). Sweeping assumptions may be made about the future economic climate in which the project has to operate. As the project moves into design, somewhat more detailed data is used. Site specific evaluation of the soil conditions, topography, environment, and regulatory requirements will certainly be undertaken. Many assumptions will still be made, however, to varying degrees of accuracy. Much remains guesswork, as for example the hydraulic design of a channel must assume roughness based on operating characteristics such as vegetation level and future grading maintenance which can only be guessed at during the design process itself. Still, the design process is characterized by a great deal of analysis based on some data and a number of assumptions.

In the construction process, there is a gradual transition from assumption to certainty. This transition can be visualized in any number of ways. The soils information is sketchy at the outset, but by the time the excavation is complete, the soil conditions are very well known. The initial schedule and estimate are projections at the start, but, by completion, the final time required and project cost are clear. There is thus an abundance of data developed during construction. It comes in an enormous variety of formats: costs, labor hours, quality control tests, material tickets, daily logs, maintenance records, productivity measurements, inspection reports, and on and on. The cost of capturing the data – mostly with pencil and paper or, at best, keyboard transcription of conventional records, is prohibitive. The accuracy and quality is also, at best, random.

Interestingly, perhaps because of the flood of data, or perhaps because of the variety of formats in which the data is presented, or because of the accuracy and quality, there is relatively little analysis related to all of the data which arises. In fact, most of these data are filed, tossed, or processed into a form where most of the enduring value is lost. Some of it may filter back into an experience database (formally or informally) for use in future projections. Very little analysis for the purposes of improvement is undertaken. We, in fact, find ourselves adrift without the information needed for decision making or the facts needed for analysis in a sea of un-harvested data.

The potential is very high. Instrumentation technology has taken us past the days when we used time-lapse films to “record it all” and then strip the data. Sensors can measure pressures to determine loading cycles, load cells can measure the bucket fill factor for every cycle and eliminate “the factor”, GPS can accurately relate velocity profiles with haul road geometry to eliminate the gross assumptions in rim-pull curves. Technology has driven the cost of data storage and computation down rapidly. The data can be stored, rules can be developed to modify the format of the data, and analysis can then proceed with confidence and accuracy. Many process improvements can be imagined. Feedback loops on the accuracy of the geotechnical predictions or the safety or constructibility of a design could be implemented. Construction processes could be improved by direct analysis of the progress of the work under a given set of operating rules. Product quality improvements could be directed through the development of a larger set of quality and process measurements. We can move away from the charts, graphs and standards which entrench historical performance to an age when real time data are collected and used to develop new methods and new levels of performance.

To do this we need to research and test the construction application of instrumentation technologies to collect and store data autonomously. We need to research the technologies needed to transmit these data packages from remote and changing locations. We need to research the methodologies needed to process, archive, understand and use these data. We need to research how the data can be integrated and used in all phases of the construction process. Our research needs stretch from instrumentation and communication technologies to data processing, data visualization and total project integration.

The authors do not mean to suggest that simple data mining and the development of giant databases will solve the problems of the future. Unquestionably, any analytical process must begin with an understanding of the principles and the objectives of the analysis. Still, it is hard to deny that at present the construction process is data rich but analysis poor. Data are developed at every stage in the delivery process, and improvements in the activities and systems are possible right across the spectrum. As means of obtaining these data remotely, transmitting them, storing them, and performing computations become less expensive and difficult, we must develop methods to relate the data generated in each part of the process to the final product, and through that knowledge improve the process.

The authors share a vision of a data driven construction industry where decisions are taken on facts and not conventional wisdom; where operations are planned using real data and not historical standards. We believe that we are at the threshold of a time when technology enables us to eliminate the high cost and low quality of clerical systems and move to an age of autonomous, low cost, high quality, real time data collection. Our research agenda can not be blind to the opportunities.

BACKGROUND OF AUTHORS

Mike Vorster is the David H. Burrows professor of construction Engineering and Management at Virginia Tech. He has an established record in equipment management and operations improvement. This work includes the use of on board instrumentation, GPS and RFID data in the planning and analysis of equipment operations. He has played a leading role in the establishment of the Virginia Tech Vehicle Tracking Group for the development and use of GPS technologies in construction field operations. He has served as Associate Dean for Research in the College of Engineering at Virginia Tech, which has led to a broad-based interdisciplinary view of engineering research as a whole.

Ken Walsh is an assistant professor of construction in the Del E. Webb School of Construction at Arizona State University. A geotechnical engineer by training, he was drawn into a construction focus through 8 years of consulting engineering practice emphasizing deep foundations and environmental remediation, fields in which the design and construction phases are necessarily integrated. He has been involved in nearly $1.2M of funded research since 1994 as either a PI or co-PI. This work has related primarily to the integration and assessment of the impacts of design assumptions on field performance in the residential and heavy civil sectors.