The Incident Reporting System (IRS)

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Abstract

Instead of investigating accidents, Incident Reporting Systems **(**IRS) analyze incidents. Because incidents happen more often than accidents, larger samples can be obtained by collecting incident reports. Incident reports can be used to gain insight into the factors leading to failures. IRS have been successfully used in the aviation industry and in anesthesiology. This report discusses the use of IRS in the prevention of construction failures. Anonymous, Internet-based IRS in construction offer a unique opportunity to increase the safety of the construction process and constructed facilities, to improve the quality of construction materials and to optimize the allocation of construction research funds.

Introduction

Despite computer-aided-design technology and sophisticated scientific theories, construction failures have not ceased to occur.

Table 1 shows estimates of the annual risk of construction casualties for the U.S. construction industry (Eldukair and Ayyub, 1991). The values were calculated using samples from the years 1975-1986.

Description	Values
Annual number of deaths (failures)	456
Annual number of deaths (accidents)	1,569
Annual number of injuries (failures)	2,515
Annual number of injuries (accidents)	968
Total number of deaths	1,985
Total number of injuries	3,483
Annual cost of failures in dollars (direct and indirect costs)	14.4×10^{9}
Annual U.S. construction volume in dollars	300×10^{9}
Annual financial risk of structural failures	48×10^{-3} (approx. 5%)
Size of construction work force in U.S.	6,000,000

Table 1. Estimates of annual risk of construction casualties for the U.S. construction industry (Eldukair and Ayyub, 1991).

An empirical study of 800 construction failures performed by Matousek and Schneider (1976) at the Swiss Federal Institute for Technology (ETH) in Zurich indicates that approx. 75% of construction failure cases are due to human error. The remaining 25% of construction failures are caused by consciously (intentionally) accepted risks. Estimates for accidents in aviation indicate that approx. 70% of accidents are due to human errors (IATA, 1989). Matousek and Schneider's study also shows that the majority of construction failure cases attributed to human errors of engineers are due to insufficient knowledge, underestimation of effects/influences and ignorance, carelessness and negligence. *Figures 1 and 2* show some of the results of Matousek and Schneider's study.

Systematic methods of error prevention, from design to construction, were also developed at ETH (Matousek, 1982; Matousek and Schneider, 1983; Schneider, 1997). So-called checkpoints during the design process are now well known. At these points, the plausibility of the used data is analyzed. Of great importance to design professionals are also organizational measures like proper project documentation and effective communication procedures. Particularly the concept of *hazard scenarios* merits a special mention here. Hazard scenarios, as part of the so-called *safety plan* of engineering designs, entered Swiss building codes in 1989. However, the main difficulty while searching for hazard scenarios is finding the ones relevant to a particular project. Quality Management techniques are nowadays also being used in the construction industry.

Unfortunately, the research of Matousek and Schneider on the safety of buildings has not been followed by further work in this area. For example, the ETH project "Risk and Safety of Technical Systems" was concluded without further follow-up research.

Even though each construction failure is to be regretted, each failure provides valuable information that may be used to prevent similar failures. Therefore, to prevent construction failures, they should be studied systematically. Knowledge gained from such studies should be organized and made available to all interested parties, e.g. in the form of electronic databases or on Internet pages. Also, the systematic analysis of construction failures can occur in the form of individual case studies including a description of the failure case and the lessons derived from it (Gnaedinger, 1987). Furthermore, construction failures can provide the information required to define the hazard scenarios of engineering designs.

Unfortunately, only the most spectacular failures are reported and therefore broadly discussed. Information from less spectacular cases is often kept secret, mainly for legal reasons and fear of the reputation of the parties involved. Organizations involved in liability suits often do not provide access to information concerning present and past failure cases. The knowledge gained from construction failures is therefore insufficiently organized and at the disposal of a limited number of persons.

Independent, state-run institutions, like universities, are well suited for the scientific investigation of construction failures. Primary reasons for this are their impartial nature, the social and economical relevance of the built infrastructure and the high costs of these investigations.

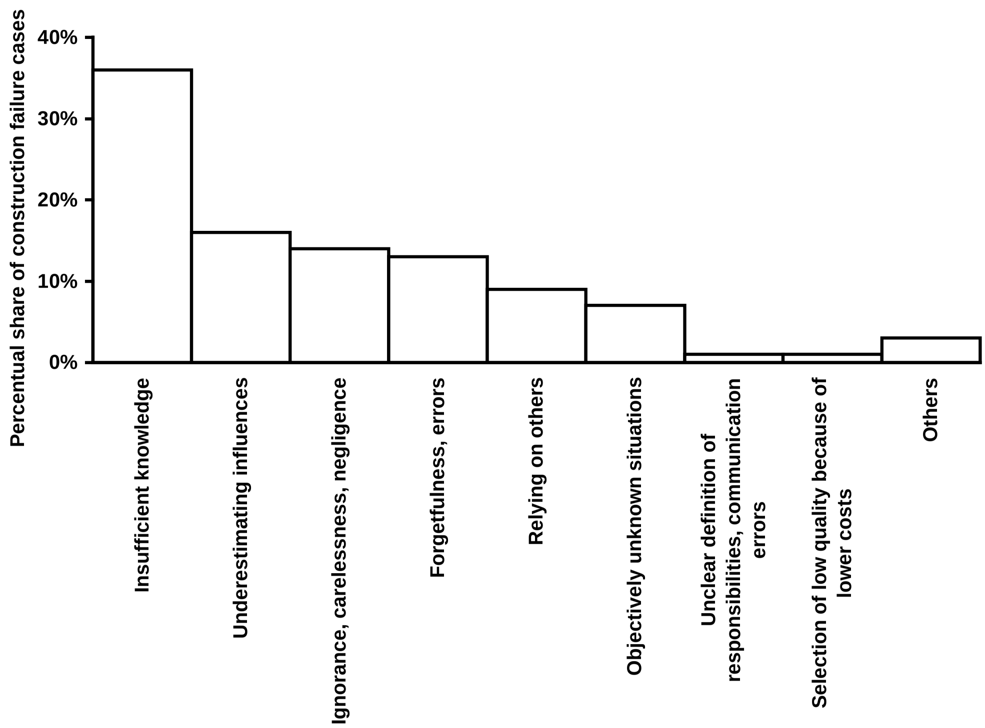

Figure 1. Pareto Chart of construction failures due to human errors of engineers (data extracted from Matousek and Schneider, 1976)

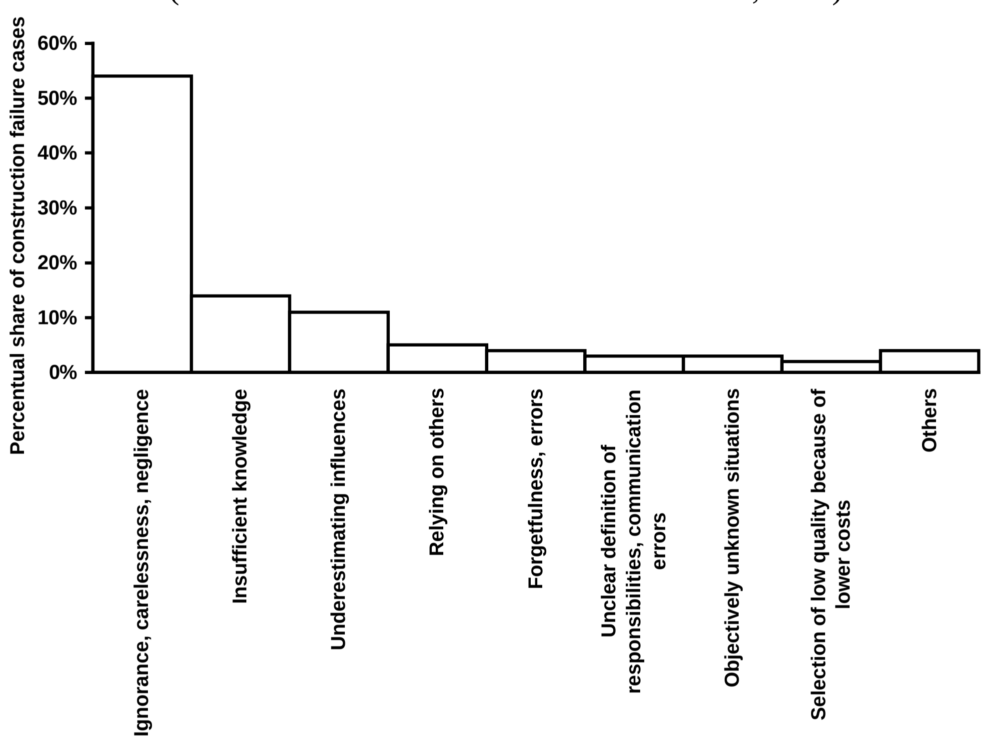

Figure 2. Pareto Chart of construction failures due to human errors of contractors (data extracted from Matousek and Schneider, 1976)

Construction Failure Prevention: Today

Although failures will probably not cease to happen, we engineers have the moral and professional obligation to take steps in order to reduce their frequency. The following strategies to prevent failures have so far been suggested and partly implemented:

1. *Education.* Besides presenting successful design examples, courses at universities should also include case stories exemplifying errors to be avoided. Case studies of construction failures are ideal for this purpose (Feld and Carper, 1997; Gnaedinger, 1987; Kaminetzky, 1991; Ortega, 1998; Petroski, 1994, 1993 and 1992).

2. *Research.* Failures are sometimes caused by gaps in scientific knowledge and therefore, are useful for identifying main points of emphasis for scientific research.

3. *Failures database.* The data extracted from failure analyses should be systematically organized in electronic databases and made available to all interested parties. One such database is currently in operation at the University of Maryland.

4. *Building codes.* Failures also point to gaps in building practice. Building codes need to be updated to take account of the conclusions reached from failure analyses. A failures database could support this endeavor.

5. *Journals.* Failures should be published and openly discussed in professional journals. The *Journal of Performance of Constructed Facilities* of the American Society of Civil Engineers and *Technology, Law and Insurance* of the International Society for Technology, Law and Insurance are two such examples.

6. *Associations*. Further national and international organizations like the *Forensic Engineering Division* of the American Society of Civil Engineers and the *International Society for Technology, Law and Insurance* should be established to promote failure prevention and spread the lessons learned from failures.

7. *Events.* Further congresses, conferences and conventions are needed to disseminate the lessons learned from failures. Examples are the *Forensic Engineering Congresses* held by the American Society of Civil Engineers and the *International Conferences on Structural Failure, Product Liability and Technical Insurance* held by the International Society for Technology, Law and Insurance.

8. *Collaborative design.* Architectural and engineering projects should be carried out in a collaborative manner. In

most cases architectural and engineering projects are completed sequentially, with the architectural design, the engineering design and the actual construction undertaken by the architect, the engineer and the contractor, respectively. The sequential, fragmented design and build process has severe disadvantages. Besides holding back creativity, it is detrimental to construction projects because engineering and constructability concerns are not addressed early, when project changes are most economically implemented. Collaborative designs should be carried through by architects, engineers and contractors working closely together from the beginning until the end of a construction project (Lin and Stotesbury, 1988).

9. *Design-construction reviews.* Carefully planned and strategically timed review meetings should be held from the design phase until the actual construction phase (Goodden, 1996). These meetings have the purpose of reviewing the technical aspects of the architectural and engineering project. Architects, engineers and contractors should participate in these meetings. These reviews should be thoroughly documented. All relevant problems should be discussed as early as possible, especially because it is well known that the cost of carrying out modifications increases as a project progresses.

10. *Particular attention to the construction phase.* The loading cases relevant to each step of the construction phase should be carefully analyzed. The adequacy of the selected temporary structures and the value of the chosen safety factors should be justified and documented (Carper, 1987).

11. *Inspection of construction sites by designers.* Architects and engineers should carry out inspections of the construction process to ensure that structures are built safely and according to plan (Carper, 1987).

12. *Peer reviews.* Complex, unconventional or large architectural and engineering projects should be reviewed by an independent professional or organization (Bell, 1989; Zallen, 1990).

13. *Monitoring.* Exceptional or unconventional structures should be monitored not only during the construction process but also during the operative phase. A monitoring strategy should be developed during the design stage, before construction has started. In this manner, the behavior of these structures can be studied and conclusions for future designs can be drawn.

14. *Unified risk insurance.* A unified insurance offered by

insurance companies should cover all members of a project team (Vince, 1989). This will help reinforce cooperation between participants in construction projects.

Construction Failure Prevention: Tomorrow

The annual figures for deaths, injuries, and financial losses due to construction failures shown in *Table 1*, underscore the need to increase safety in the construction industry. Industrial sectors with highly developed risk-consciousness, like the aeronautical industry, use advanced methods to ensure the safety of their technical systems. A possible transfer of these methods to the construction industry ought to be studied. One such method is Incident Reporting Systems (IRS).

According to Staender et al. (1997), an incident is "any deviation from the expected course, with a strong potential for an adverse outcome" (*Figure 3*). IRS originated in aviation, where the safety standards are especially high. The Aviation Safety Reporting System (ASRS) was established by the Federal Aviation Administration's Office, and is administered by NASA. It covers incidents reported by pilots, dispatchers, airport personnel, air traffic controllers, mechanics, and cabin crew. Further information concerning incidents is obtained directly from confidential telephone interviews with incident reporters. The reports are handled anonymously and standard report forms can be downloaded from the Internet. ASRS provides two regular publications, *Callback* and *ASRS Directline* [1]. They contain excerpts from ASRS reports and summaries of ASRS research studies. There is also an ASRS Database, which cannot be accessed from the Internet. However, a selection of recent, relevant cases is published in the Internet.

Motivated by the success of the ASRS, the Department of Anesthesia at the University of Basel (Switzerland) introduced in 1996 the Critical Incident Reporting System (CIRS). The CIRS covers incidents in anesthesia and offers a database that is accessed from the Internet [2]. The primary reason for analyzing incidents, rather than accidents in anesthesia, is the larger sample provided by incidents, compared to accidents. Incidents are entered anonymously from standard reports on the CIRS homepage. A preliminary analysis (Staender et al., 1997) has shown that 34% of the reported incidents concerned communication problems, while 30% concerned lack of concentration, 30% insufficient experience, 30% omission of checks, and 28% misjudgment (the sum totals more than 100% because several incidents were due to more than one cause). As can be seen, all reported cases concern human error. Even though the CIRS very probably does not produce a representative sample of incidents, it can help identify patterns of problems that might otherwise not be detected. The CIRS was designed mainly as an educational tool, for example for delivering data for operating theater simulations. The anonymity provided by the CIRS does not allow interviews with the incident reporters in order to gain

[1] http://olias.arc.nasa.gov/ASRS/ASRS.html
[2] http://www.medana.unibas.ch/cirs/

better understanding of the causes leading to incidents. However, comments may be input by users of the CIRS Database, which can lead to some kind of discussion.

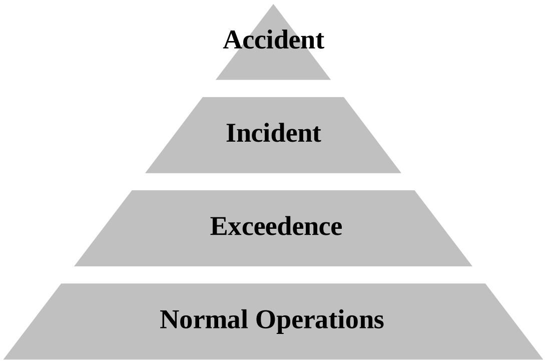

Figure 3. The various modes of operation of a technical system. The width of the pyramid segments indicates the frequency of the different operation modes (figure as presented by Schmid and Staender, 1999).

The Swiss Reinsurance Company, the Institute of Work Psychology at ETH and the Department of Flight Safety at Swissair are performing further research in Incident Reporting. The purpose of the project "Human Factor" is to study human behavior in complex high-risk systems (Klampfer and Favre, 1997). In this project, incident reports provided by Swissair are analyzed by the Institute of Work Psychology. The incident reports are generated by the Air Data Acquisition System (ADAS) which records in-flight data (Rüegger, 1990). Incident reports are automatically triggered as soon as flight variables exceed predefined threshold values and pilots do not need to be aware of an incident for it to be reported. Therefore, ADAS allows the analysis of dangerous yet unrecognized situations. Because ADAS guarantees confidentiality, personal interviews with the reporters are used to gain further insights into the incidents' causes.

The conceptual ideas behind ASRS, CIRS and ADAS can be productively transferred to the construction industry. Currently at the Institute of Technology Management of the University of St. Gallen research is under way to design and implement an Incident Reporting System for construction. The main reasons for using an IRS in construction are the following (see also Rüegger, 1990):

1. Incident reports provide larger samples than accident reports.

2. Individuals involved in incidents are more willing to report than individuals involved in accidents. An anonymous and confidential IRS can increase this willingness.

3. If confidentiality is guaranteed, follow-up personal interviews may lead to deeper insights than individual incident reports.

4. The analysis of incident reports is far more economical than that of accident reports.

5. Since incidents do not lead to adverse outcomes, they point to errors to be avoided and deliver remedial and recovery measures to surmount the incidents. Therefore, in many cases not only the problems are identified, but also the solutions are provided.

IRS can be more advantageous if their data sample is broadened by collecting international data using the Internet. The Internet opens up the unprecedented possibility of collecting data at a very low cost and provides the opportunity to disseminate information at almost no cost. Of critical importance for the usefulness of an IRS is the quality of the report forms. They should be easy-to-use, cover all possible modes of near-failure and facilitate the statistical analysis of the input data. The value of an IRS lies in the lessons learned by the incidents. Therefore, it is important to regularly update the IRS database and to publish and disseminate the latest findings as soon and as broadly as possible. The productive use of an IRS in construction could lead to safer construction. It could also help to improve products and materials and to focus the activities and resources of construction research.

Summary and Conclusion

This report discussed several strategies for preventing construction failures. Among them are: case study analysis, collaborative design, design-construction reviews, peer-reviews, monitoring, etc. It also described effective strategies for human error prevention used in aviation and medicine. Particularly the Incident Reporting Systems of ASRS, ADAS and CIRS were discussed. Incident Reporting Systems in construction, combined with the speed, economy and penetration of the Internet, offer a unique opportunity to increase the safety of the construction process and constructed facilities, to improve the quality of construction materials and to optimize the allocation of construction research funds.

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