A novel solution for construction on-site communication – the information booth

Kasun N. Hewage and Janaka Y. Ruwanpura

Abstract: A recent study on construction productivity improvement at the University of Calgary revealed the direct tool time (working time) of Alberta's commercial construction to be about 51%. This study exposed inadequate communication and unavailability of required information as the main causes for a relatively lower tool time. Use of information technology (IT) to overcome widely visible communication issues was extremely limited at the construction site level. Construction companies' hesitation to adopt new technologies was well noted whereas construction workers expressed their willingness and ability to use IT at the site level. The objective of this paper is to discuss the concept and the application of a novel communication tool (called an information booth) developed and pilot tested at a construction project. The concept and the technology presented in this paper have been tested at an actual construction project resulting in improvements in construction productivity, worker satisfaction, and efficiency. This paper also elaborates the rationale for a new technological framework (and the information booth), barriers for technology implementation, research objectives, methodology, and data analysis.

Key words: information technology, construction productivity, worker satisfaction, human–technology interaction, on-site communication.

Résumé : Une récente étude sur l'amélioration de la productivité dans le domaine de la construction menée à l'Université de Calgary a révélé le temps d'utilisation directe des outils (temps de travail) dans le domaine de la construction commerciale en Alberta; il était d'environ 51 %. Cette étude a déterminé que les principales causes du temps de travail réel relativement faible sont une communication inadéquate et la non-disponibilité de l'information requise. L'utilisation des technologies de l'information (TI) pour surmonter les problèmes de communication bien évidents était extrêmement limitée sur les sites de construction. L'hésitation des compagnies de construction à adopter les nouvelles technologies a été bien notée alors que les travailleurs de la construction ont exprimé leur volonté et leur capacité à utiliser les TI sur le site. Cet article discute du concept et de l'utilisation d'un nouvel outil de communication (appelé « kiosque d'information ») développé et testé à l'échelle pilote sur un site de construction. Le concept et la technologie présentés dans cet article ont été mis à l'épreuve sur un réel projet de construction; il en a découlé des améliorations en productivité en construction, en satisfaction des travailleurs et en efficacité. Cet article traite également de la justification d'un nouveau cadre technologique (et du « kiosque d'information »), des obstacles à l'implantation de la technologie, des objectifs de recherche, de la méthodologie ainsi que de l'analyse des données.

Mots-clés : technologies de l'information, productivité en construction, satisfaction des travailleurs, interaction humain–technologie, communication sur le site.

[Traduit par la Rédaction]

Background

The construction industry faces many challenges at the beginning of the 21st century as it is forced to change and to incorporate new advanced technologies into the construction process to gain a competitive edge in the market (Abduh and Skibniewski 2003). According to FIATECH (2007), the construction industry lags behind the manufacturing and transportation industries in terms of field-level automation and the wireless and display technologies. The exact role of information technology (IT) in the construction industry is uncertain. This uncertainty springs from the continually changing nature of the technology and the numerous attempts made by the construction industry to use technologies (Brien and Soufi 1994). Despite an explosive growth of internet use in many areas of business and commerce in the late 1990s, the construction industry has not kept pace to the same degree (Brandon 2000).

The military shares several operational characteristics with the construction industry, such as outdoor environment, group work, continuously changing work locations, specialized training, and safety priorities. The military also makes extensive use of information technology to improve communication between field and head command. The success of

Received 18 January 2008. Revision accepted 10 February 2009. Published on the NRC Research Press Web site at cjce.nrc.ca on 9 April 2009.

K.N. Hewage. Project & Construction Management, School of Engineering, The University of British Columbia - Okanagan, Kelowna, BC V1V 1V7, Canada.
J.Y. Ruwanpura.[1] Department of Civil Engineering, Schulich School of Engineering, University of Calgary, Calgary, AB T2N 1N4, Canada.

Written discussion of this article is welcomed and will be received by the Editor until 31 August 2009.

[1]Corresponding author (e-mail: janaka@ucalgary.ca).

any modern military operation is dependent on real-time efficient communication technologies (Allen 2004). When real-time communication technologies were added to the manufacturing industry's work environment, they experienced improved communication and productivity (Baldwin and Sabourin 2002). Neil and Knack (1984) stated that effective communication among all project participants can stimulate cooperation and productivity.

Many research and industry reports emphasized the relationship between technology investment and productivity gains in manufacturing, banking, and insurance (Park 2003). However, such credible and documented reports are rare for the construction industry. No root level investigation has been conducted in the construction industry to understand the present and future potentials of technological adoptability (Hewage and Ruwanpura 2006*b*). Moreover, very few actual field tests have been conducted to identify the capabilities of "technologies" in actual construction site environments (FIATECH 2007).

Hewage and Ruwanpura (2006*a*) described the background and motivation to conduct research in the area of on-site communication in the construction industry. In brief, Hewage and Ruwanpura (2006*a*) conducted interviews, questionnaire surveys, and observations in four commercial construction projects in Alberta for a period of two years to identify worker motivation, communication, and productivity related issues. After interviewing 101 commercial construction workers, the researchers reported the dissatisfaction of the construction workers on the issue of available communication systems and practices. A similar problem was identified by previous researchers such as Bowden et al. (2006) and Mohamed and Stewart (2003). These researchers found that only 20% of the information passes to the operational (worker) level in a construction project. Hewage and Ruwanpura (2006*a*) also found that 45% of the interviewed construction workers (the same 101 workers), from several Alberta commercial construction sites, described their frustration concerning inadequate communication at construction sites. Workers identified inadequate communication as the main reason for low motivation and productivity (Hewage and Ruwanpura 2006*a*). Further, 51 construction site professionals and (or) managers surveyed in Alberta by the same researchers noted inadequate communication as the third most critical factor contributing to low productivity. One-on-one interviews with the senior construction managers by the same researchers revealed that they were well aware of the communication issues in the construction projects. Managers stated that they have attempted to change the communication flow through the use of existing resources in the company. Some of the attempts made by management include morning tool box meetings (a tool box meeting is a meeting time to instruct the workers before the work starts; usually a foreman conducts the meeting), radios to foremen, and fax machines and internet connections to site offices.

As outlined above, the construction industry lags behind other industries (such as manufacturing and military) in its acquisition of modern technologies for enhancement of productivity (FIATECH 2007). This means the construction industry still has the opportunity to learn from others and adapt the wide range of options and solutions to suit their specific needs. A combined framework of IT and existing managerial approaches is a solution to improve the on-site communication (Hewage and Ruwanpura 2006*b*; Silva et al. 2008).

The objective of this paper is to discuss the concept and the application of a novel communication tool (called an information booth) that was developed and pilot tested at a construction project site. This tool was first introduced to the construction industry to improve the communication between the site management and the workers. However, the tool has been modified for the benefit of many other stakeholders (Silva et al. 2008). This paper elaborates the productivity, working efficiency, and worker satisfaction improvements due to the implementation of the information booth. The paper also describes the rationale behind the implementation of the information booth.

Research description

As the first step of the research presented in this paper, the communication needs of the construction industry have been identified with the input of two major stakeholders – workers and managers. Direct construction field observations, interviews, and questionnaire surveys were conducted from January 2003 to June 2006 in Alberta (see Hewage and Ruwanpura (2006*a*) for the detailed methodology). Eight multi-storied construction projects were observed during this period. Following is a summary of the stakeholders' (workers and managers) views, some of which have been identified in Hewage and Ruwanpura (2006*a*, 2006*b*).

- Many workers described the lack of clarity surrounding the instructions and the technical details.
- Foremen could not always instruct and supervise the workers on-demand because of their other duties.
- Almost all the interviewed foremen described difficulties in accessing the real-time information from head offices. Foremen spent about 15% of their total working time traveling between the site office and the working area.
- The workers expressed a desire for the opportunity to view 3D and 4D (3D drawings with time factor) drawings, technical information, isometric views of the end product, safety information, weather information, and other information related to the outcomes of the project.
- Almost all the workers stated that they were not aware of the end product of their efforts, sometimes even for the daily work. They also prefer to know the expectations and targets of the work supported by documentation or visuals.
- Workers preferred to have audio-visual presentations (like videos) for better demonstration of safe work practices.
- Discontent with sudden changes in their working areas, congested working areas, unavailability of the tower crane for material movements, and lack of materials were other concerns expressed by the construction workers.

Following are the key observations made by the researchers on the on-site communication processes:

- A need for a mobile, real-time, rugged information source was quite apparent. It was apparent that the lack of content in communication and the ineffectiveness of the available communication tools contributed to the confusions in the site environment. In Alberta, Canada, the use of IT to overcome communication barriers on construction sites is quite limited. Two-way radios were the only observed communication device in use on construction sites during the observations conducted by researchers during the last three years (Hewage et al. 2008). None of the construction sites taking part in the research study used audio-visual demonstrations to teach safety practices. The workers who had serious accidents (lost time) on site attribute the injury to the lack of knowledge around safe and correct workplace practices.

- During the winter seasons, workers returned to the site trailer several times a day to change their clothes. Most of the workers were not informed or did not bother to inquire about the expected weather changes for any particular day.
- At large construction sites (more than 100 workers per shift), office managers had a limited awareness about the real-time site progress. They were dependent on the information provided by the on-site managers such as foremen.
- At some of the observed projects, there were close to 600 workers on site during the peak periods. In these projects, managers faced difficulties in assigning workers, machinery, materials, and tools to their working areas. This was due to congestion and material handling problems.
- A need for a real-time information system to track materials, tools, and machinery was very apparent.

Proposed IT framework

Based on the needs outlined above, a conceptual IT-based communication framework has been proposed by Hewage and Ruwanpura (2006*b*). A graphical representation of the framework is in Fig. 1. System A of Fig. 1 demonstrates a sample site office or head office communication network. System B illustrates a possible use of IT at the site level for communication purposes. The contents of this framework are explained in detail in Hewage and Ruwanpura (2006*b*).

After considering the views of workers and managers, onsite observations, and recommendations of previous researchers, the concept called an information booth has been selected for further research and development. The rationale behind the development of an information booth is described below.

- Why: It is possible to retrieve almost all the real-time information needed for construction site operations with this device. As mentioned, a device with real time information and audio-visual work demonstration is urgently needed for the construction industry.
- How: The information booth consists of a display screen (television monitor, digital SMART Board, or liquid crystal display monitor) connected to a computer. The foremen and authorized lead workers would be able to view 3D and (or) 4D images, access any site-related information, send voice messages, receive printouts of specifications and required drawings, obtain updates on work progression, and a multitude of site-customized uses. Each user can be assigned an access code depending on his or her trade, occupation, type of work, and level of responsibility.
- Where: It is possible to locate at least one information booth on a construction site or one per floor at high rises under construction and (or) at the site office.
- Who: The information booth is targeted to meet the needs of the construction site management personnel and lead workers. The booth can be used as a work demonstration tool for the other construction workers.

Information flow changes with the information booth

The information flow on construction projects was observed passing through several layers from the project manager down to the construction worker. It has been reported that only 20% of the information reaches the construction workers (from top management) because of the many layers of information transfer (Bateman and Snell 1999). Usually workers get information and (or) instructions only from their foremen and the foremen were advised by an area superintendent and the surveyors. Therefore, the overall information hierarchy of a company is dependent on the foremen's ability to communicate the required information accurately and clearly to the workers.

Figure 2 shows the present layers and links of communication on the observed construction projects. One of the main reasons to introduce the concept of an information booth was to minimize the multiple layers of communication on construction projects. Figure 3 shows the proposed information flow after the implementation of the information booth. With the information booth, information from all management layers was captured to a central location (the booth) and transferred directly to the site level. Construction managers have to decide the content (of the information) and access limitations of the information booth by maintaining regular contacts with the site managers.

The information booth is not an artificial intelligence device. There should be a responsible authority to input and update required information. At present, project coordinators in construction sites manually and (or) personally transfer required information from site office to the operational level. After the implementation of the information booth, one of the main duties of project coordinators will be to update and maintain the information booth database with the required information. Silva et al. (2008) explained the information updating and discrepancy handling process of the information booth in detail. Foreman and workers will be instructed to contact the site superintendent and (or) engineer immediately if there is a discrepancy in the information received through the information booth and on-site instructions. The information booth provides a direct audio-visual communication link between the site and office managers. Project coordinators will regularly check the accuracy of the contents in the information booth.

Rationale for the methodology development

Participants of the pilot study were carpenters and their main construction activity during the pilot study period was erecting a wall formwork. Figure 4 describes the research process and the time duration for each research activity. The pilot study was conducted for a period of 15 weeks.

To identify the effects of the information booth on productivity, working efficiency and workers' satisfaction were measured. All possible efforts were taken to keep other influencing factors (e.g., weather) unchanged. Observations were conducted (before and during the use of the information booth) when the temperatures ranged from +5 to –10 °C. Dozzi and AbouRizk (1993) noted almost no efficiency losses in gross skills of construction workers up

Fig. 1. Proposed information technology-based communication framework for construction industry.

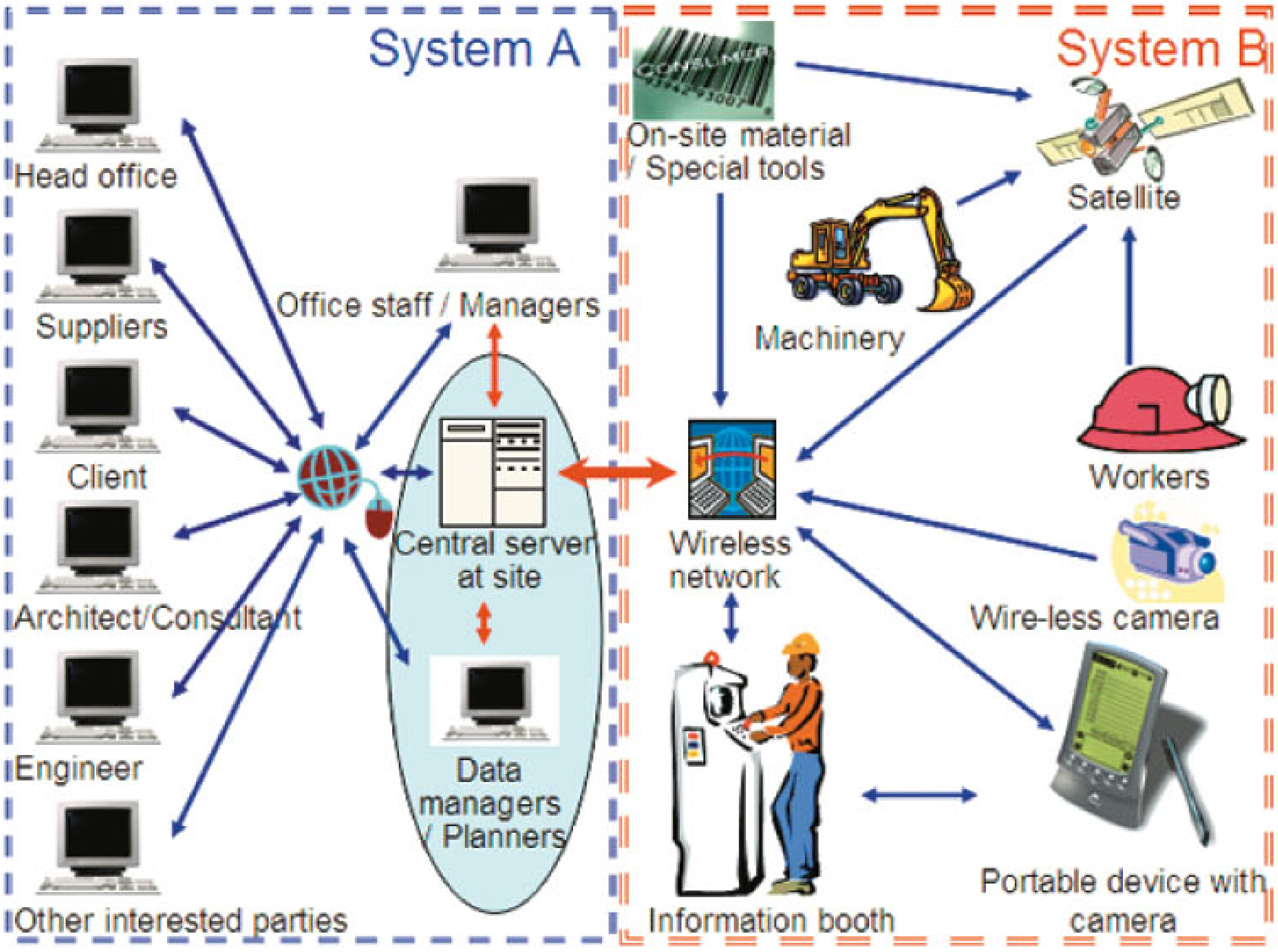


Fig. 2. Information flow on construction projects – before the information booth.

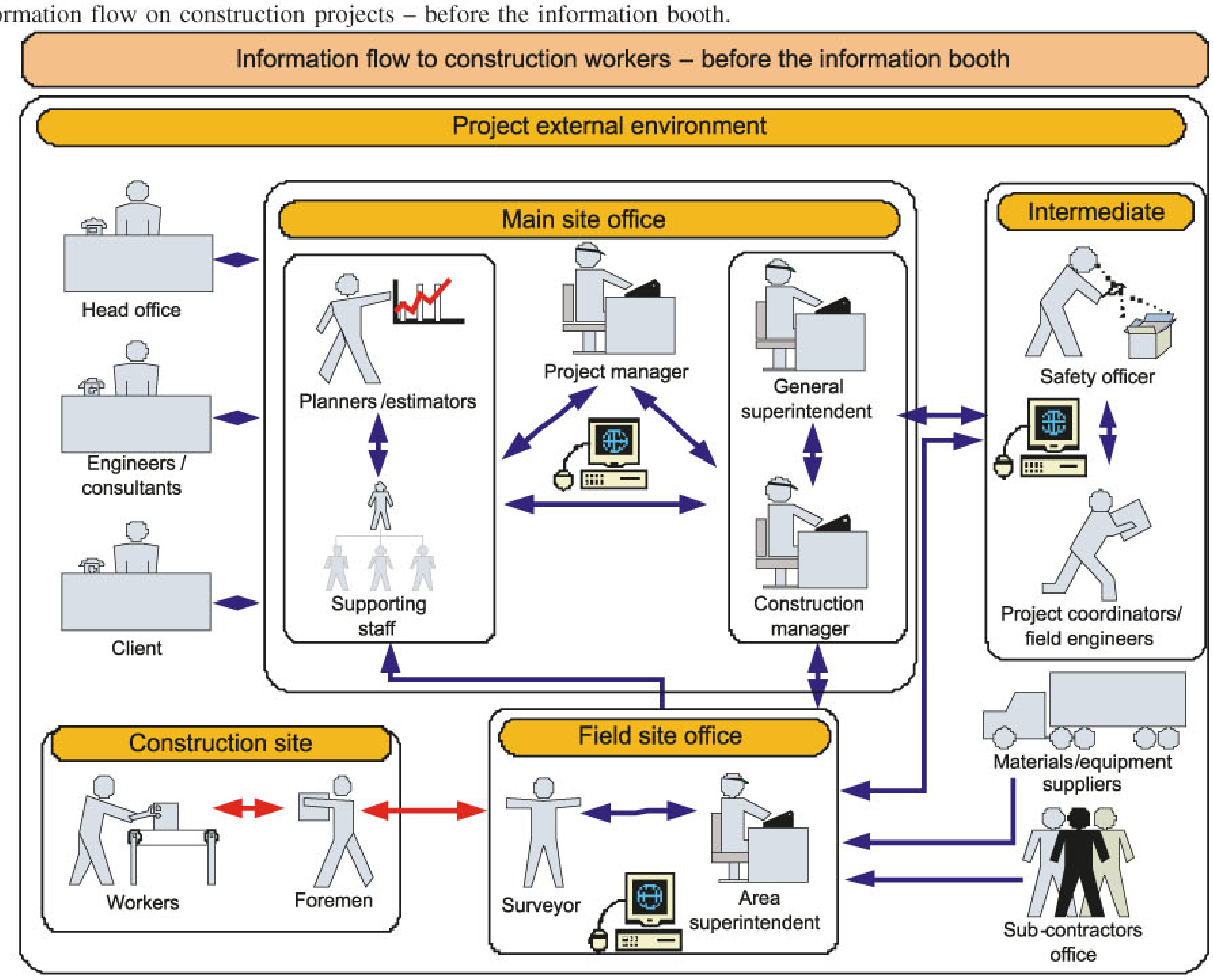
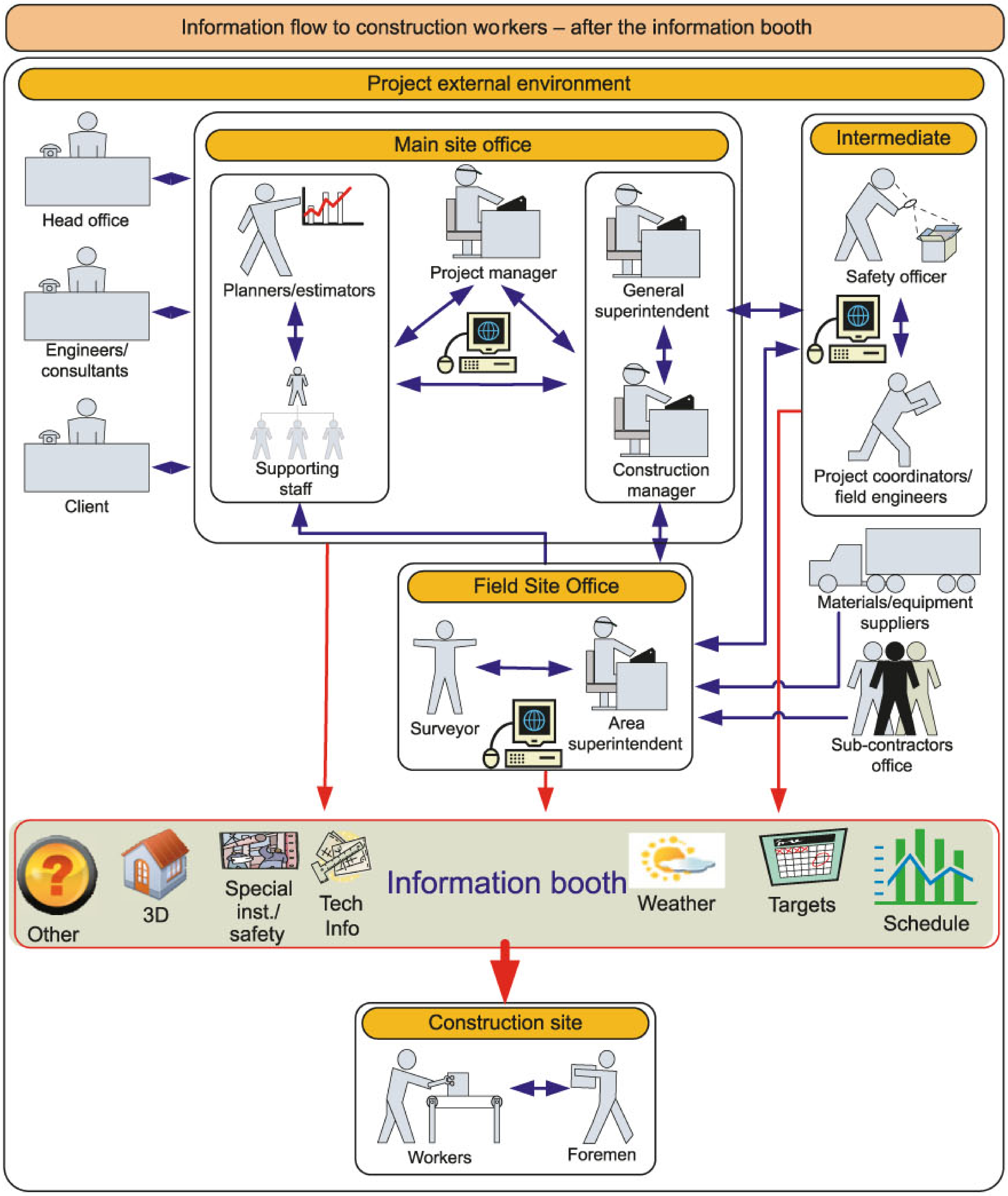


Fig. 3. Proposed information flow in construction projects – after the information booth.



to –10 °C. Only the wall formwork (carpentry) was observed for the comparison purposes as considerable variations in tool time was noted by Choy and Ruwanpura (2006) and DaSilva (2006) with other types of formwork, concreting, and re-bar. The observed project has previously experienced a learning curve factor of 0.95 for each week for retaining wall formwork; which means the company was predicting an output increase of 1.05 (1/0.95) after each week of formwork activity. Thomas et al. (1986) analysed five learning curve models and concluded that the cubic model (Fig. 5) has the best coefficient of determination for construction activities over linear models. Further, the same authors mentioned varying learning curve factor over time. According to Fig. 5, the workers achieve a slow learning rate after completing 30% of the units. No observations were made by the researchers during the first two weeks of the wall formwork because the learning curve could have had a considerable impact. Workers had completed the first lift and about 70% of the second lift (refer to Fig. 6) of the formwork and concreting of the retaining wall before the start of pilot study observations. This approach was chosen to ensure that the comparison of the productivity, efficiency, and worker satisfaction before and after the information booth was reliable and valid.

Fig. 4. Pilot study research process and timelines.

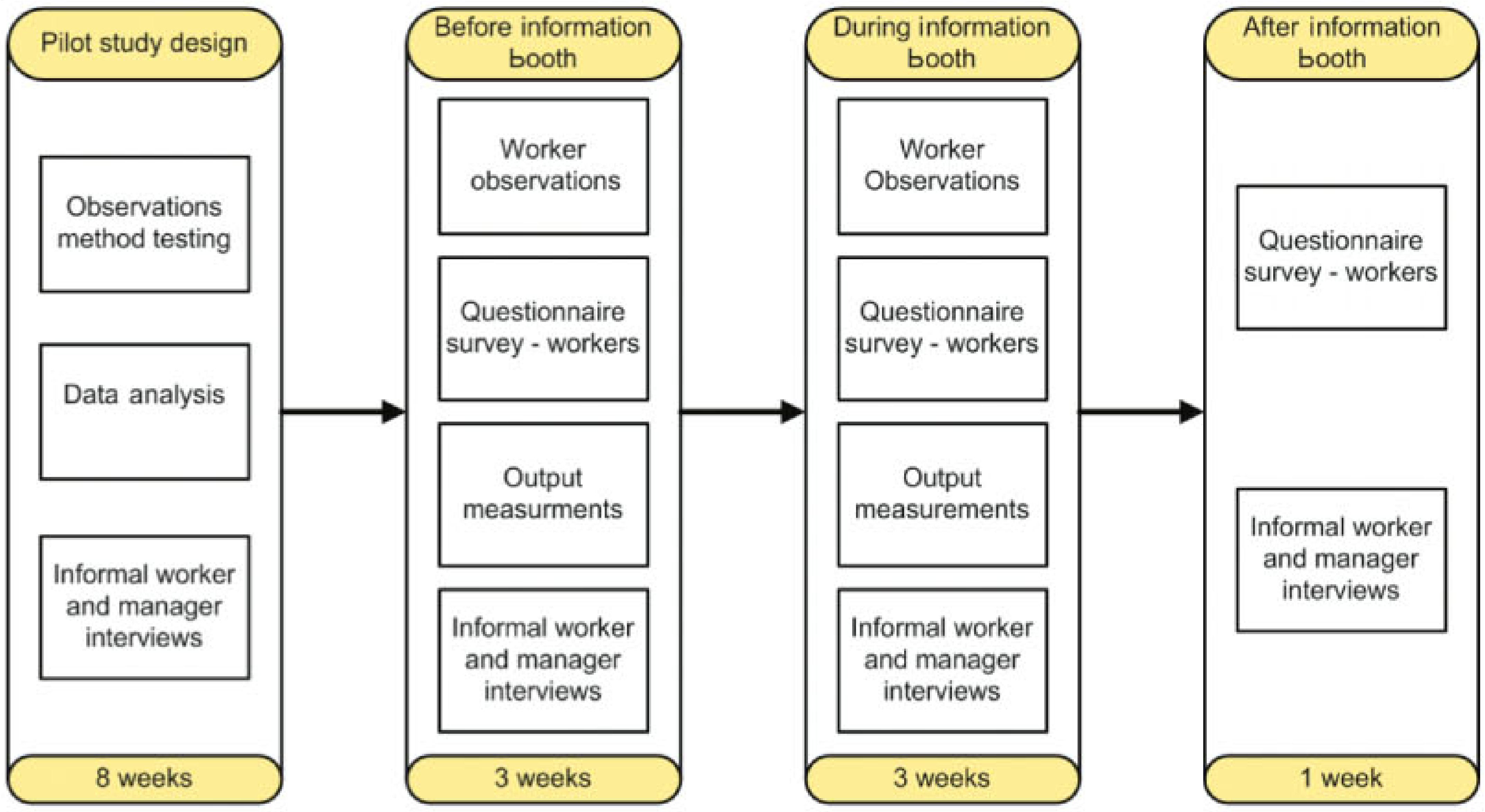


Fig. 5. Learning curve models (adopted from Thomas et al. 1986).

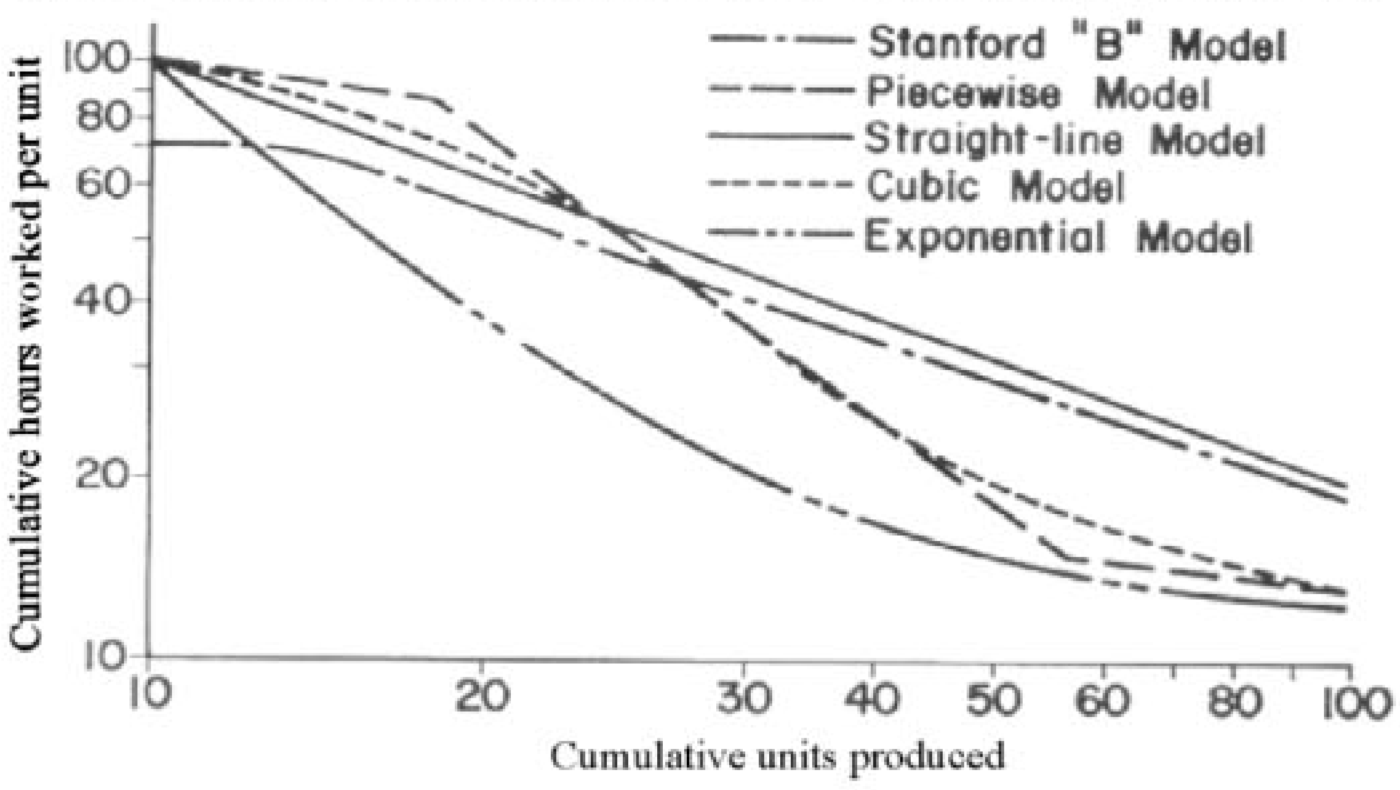
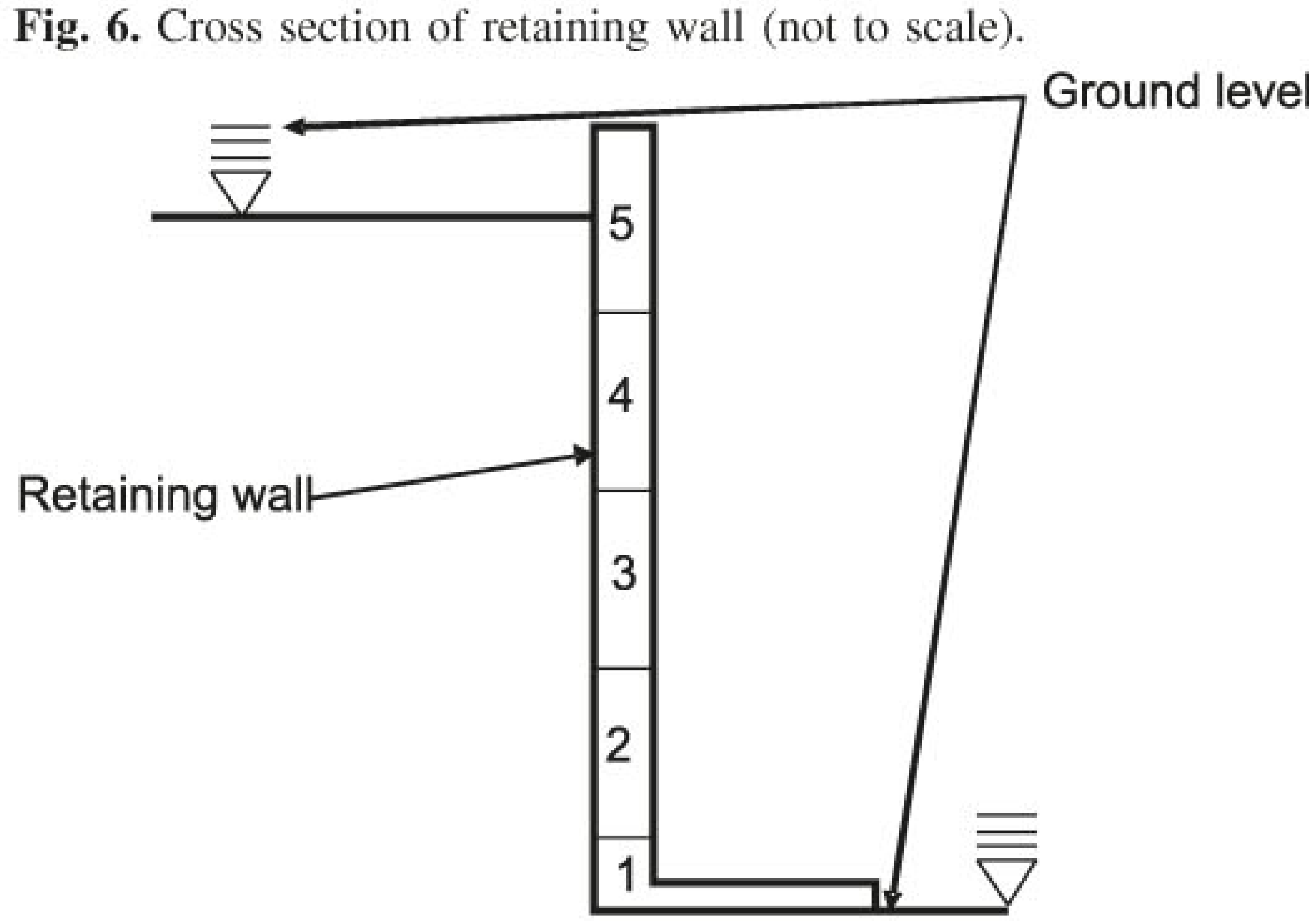


Fig. 6. Cross section of retaining wall (not to scale).



Research methodology

A brief description of research methodology is presented below.

Initial interviews and observations

The first eight weeks of the pilot study were used to identify the needs and expectations of each party – managers and workers – through interviews and observations (Hewage et al. 2008). During this period, hundreds of informal observations and open-ended interviews were conducted with the managers and the workers.

Observations

The observations were conducted on continuous 5 min intervals from 0700 to 1200. Observations were stopped at noon for lunch at which time site staff usually changed the work assignments for the afternoon based on the progress of the morning shift. Therefore the impact of the information booth was limited to morning meetings and the activities of the morning shift. There were three full-day observations, which were conducted to verify the afternoon work assignment changes.

These observations were conducted with the use of a wireless camera and two additional research assistants. A wireless camera was used to minimize the observational disturbances to construction workers and to facilitate continuous observations during unfavourable weather conditions. Third party (research assistants) observations were conducted to minimize the bias of the researcher in the 'comparison observations' (where the working time distributions were compared before and after the implementation of the information booth).

Interviews and questionnaire surveys

Three rounds of questionnaire surveys were conducted with the same sample (carpenters) during the pilot study period. The same questionnaire was given before and after (on the last day) the use of the information booth. Additional questions was asked in the middle of the pilot study to understand the workers' expectations and suggestions for improving the information booth. All the questions were rated on a 1–7 Likert scale except the last question, which was about the general opinions of the workers regarding any issue related to communication.

Content stored in the information booth

The information booth tested during the pilot study was an audio-visual (Microsoft PowerPoint) presentation with

Fig. 7. Working time distribution (before the information booth).

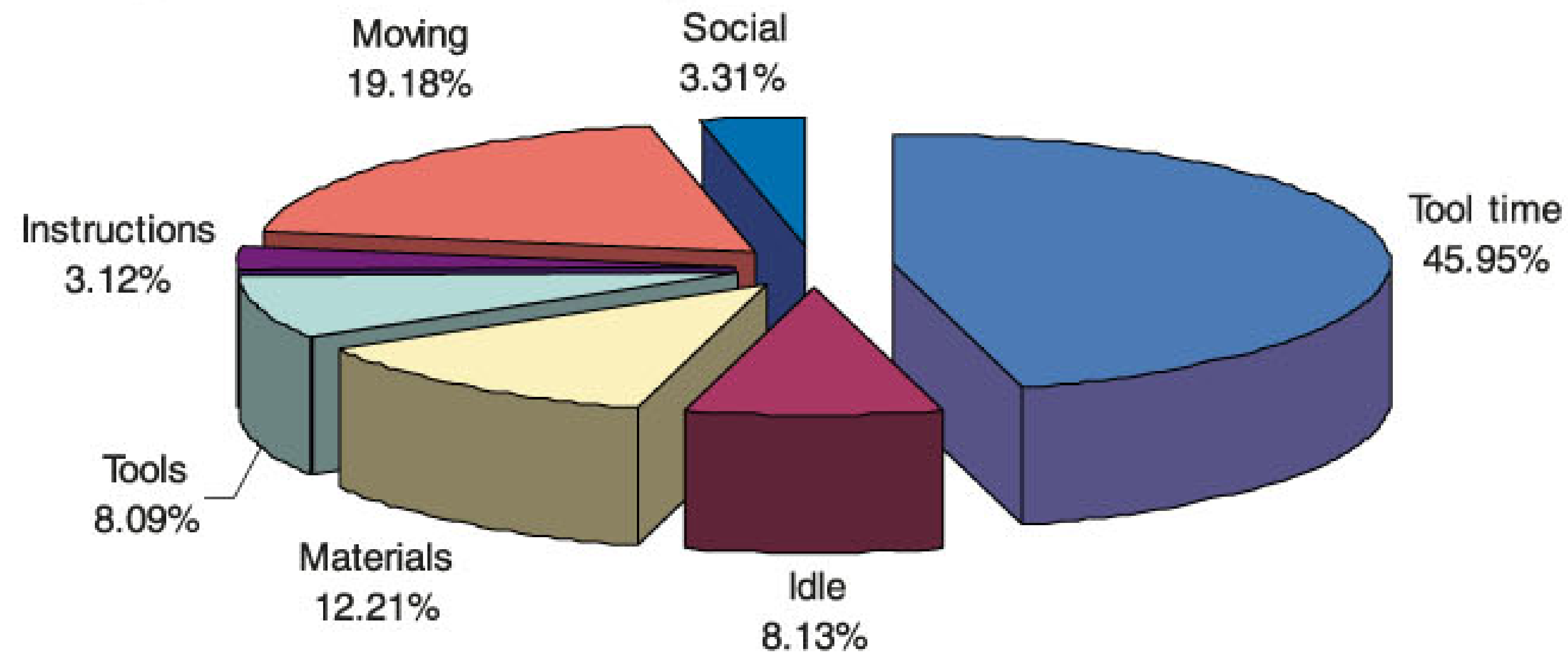


Fig. 8. Working time distribution (after the information booth).

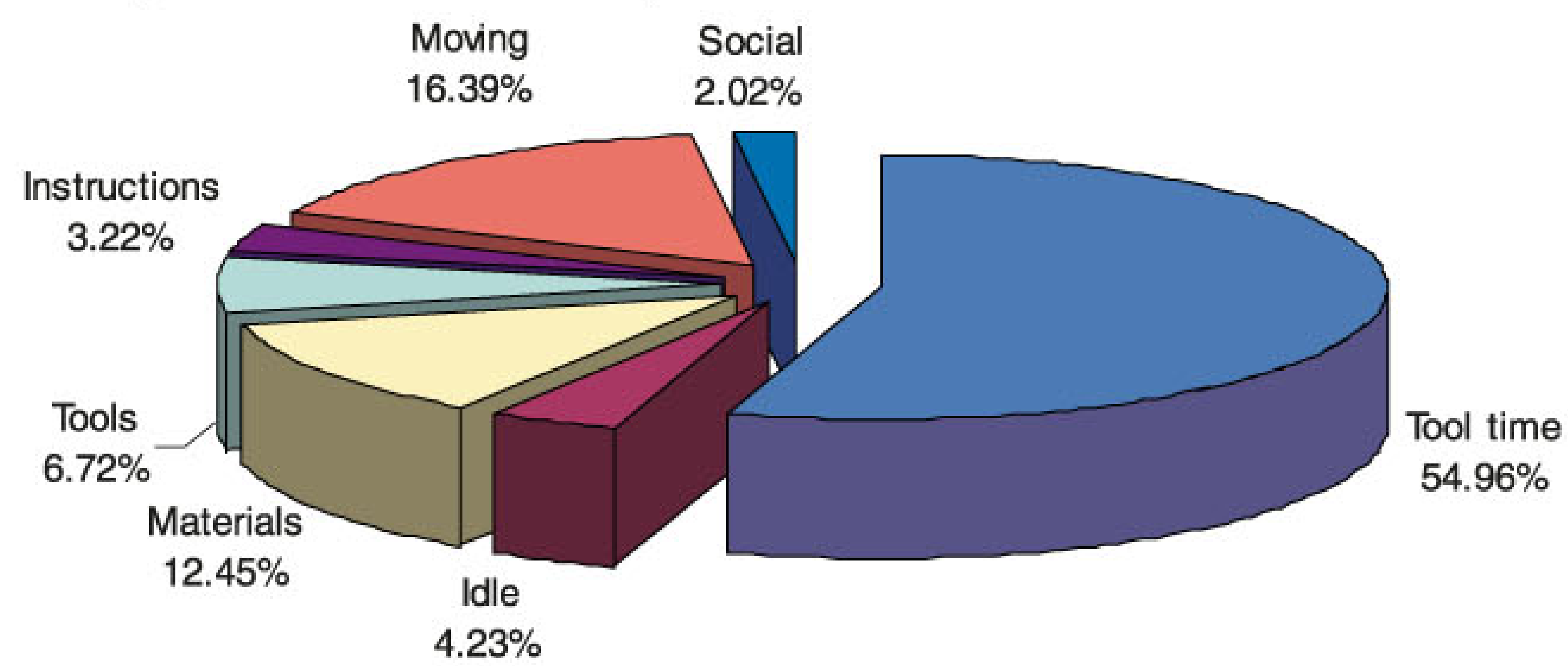
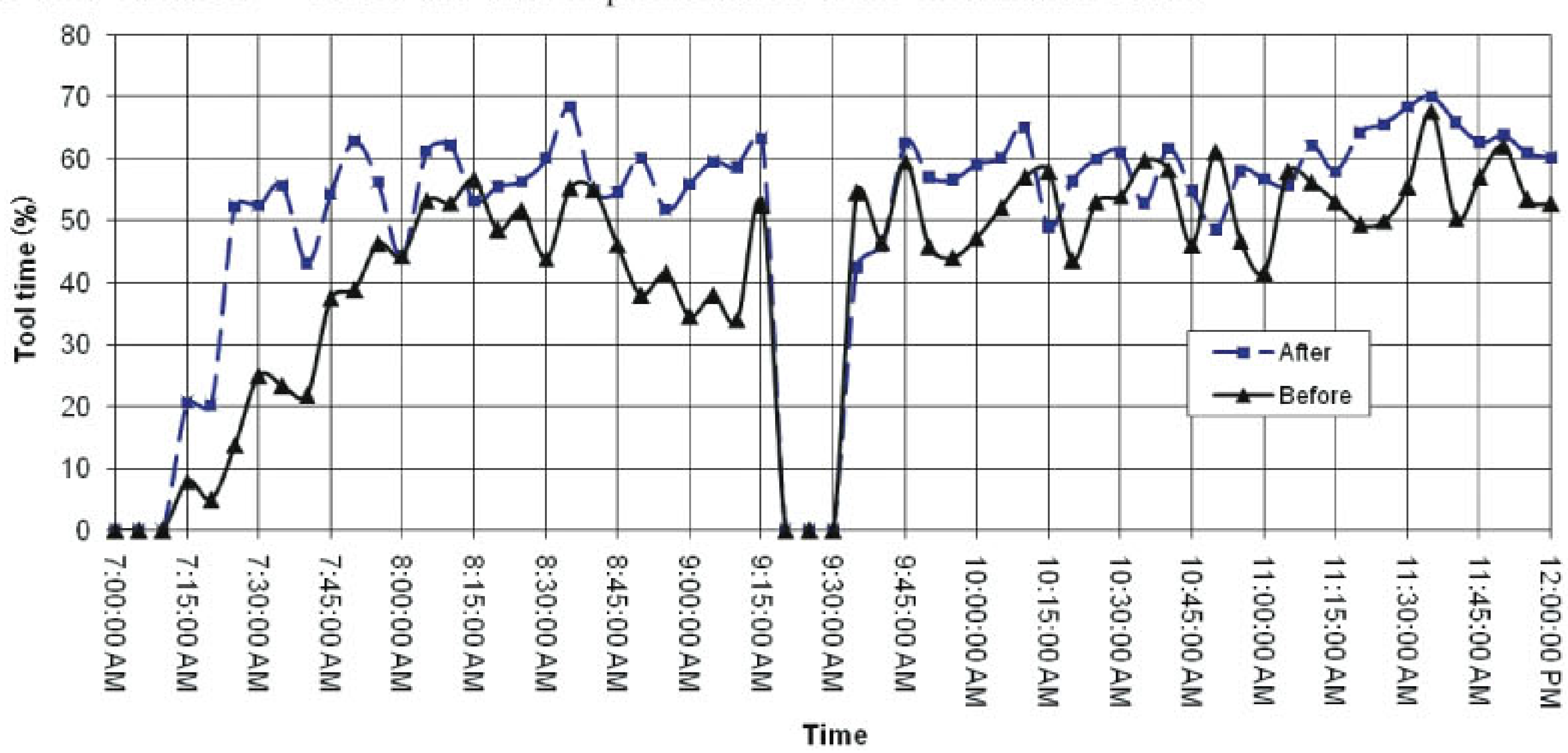


Fig. 9. Average tool time variation — before and after implementation of the information booth.



the explanations and instructions for the day's work. Verbal clarifications were then provided by the foremen. The researcher assisted the foreman in explaining certain technical and safety related information. An overhead projector, a laptop, and a projection board and (or) screen were used for this purpose. The information presented daily to the workers during the pilot study period included:

- Daily targets with expected timelines for each task.
- Work assignments for each worker (or assignments of small group).
- 3D drawings of the assigned construction work.
- Isometric – 3D pictures of the end product of the construction.
- Long-term targets and expected future construction activities.
- Weather information and predictions.
- Safety instructions.
- Special technical information needed.
- Results of the previous research work at the University of Calgary related to working efficiencies and worker motivation.

Pilot test results

The participants of the pilot study were carpenters and their main construction activity during the pilot study period

Fig. 10. Average idle time variation — before and after implementation of the information booth.

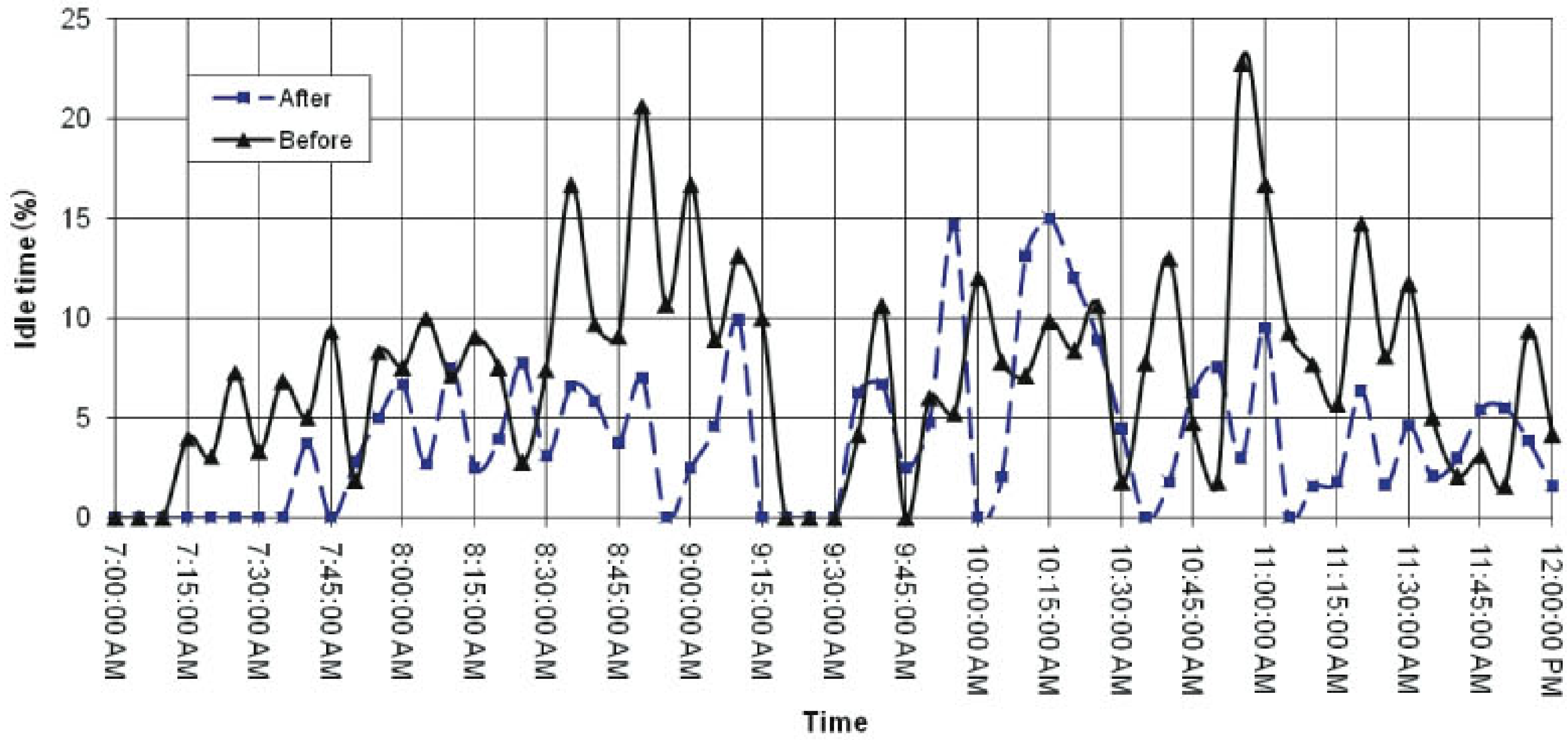


Fig. 11. Average material time variation — before and after implementation of the information booth.

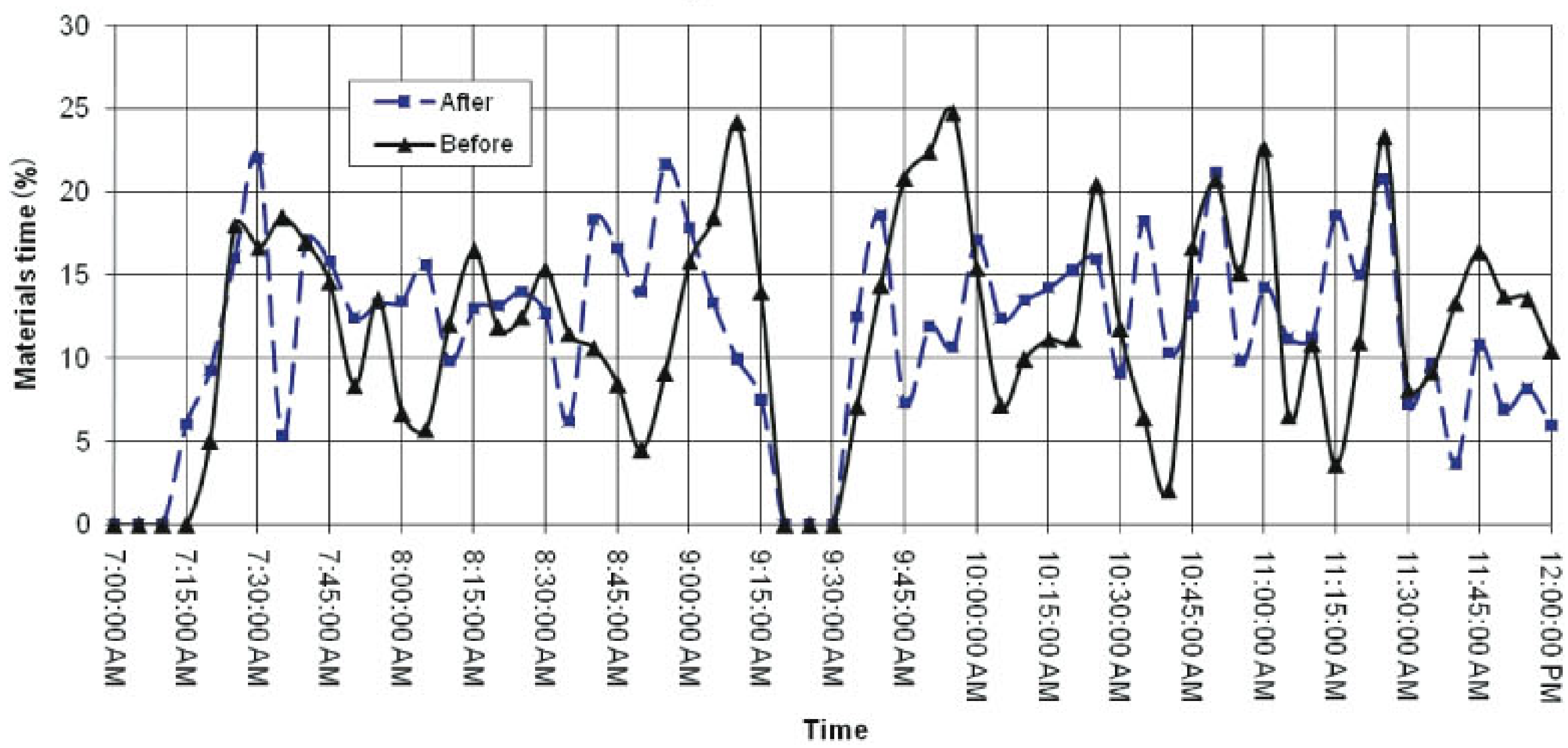


Fig. 12. Average socializing time variation — before and after implementing the information booth.

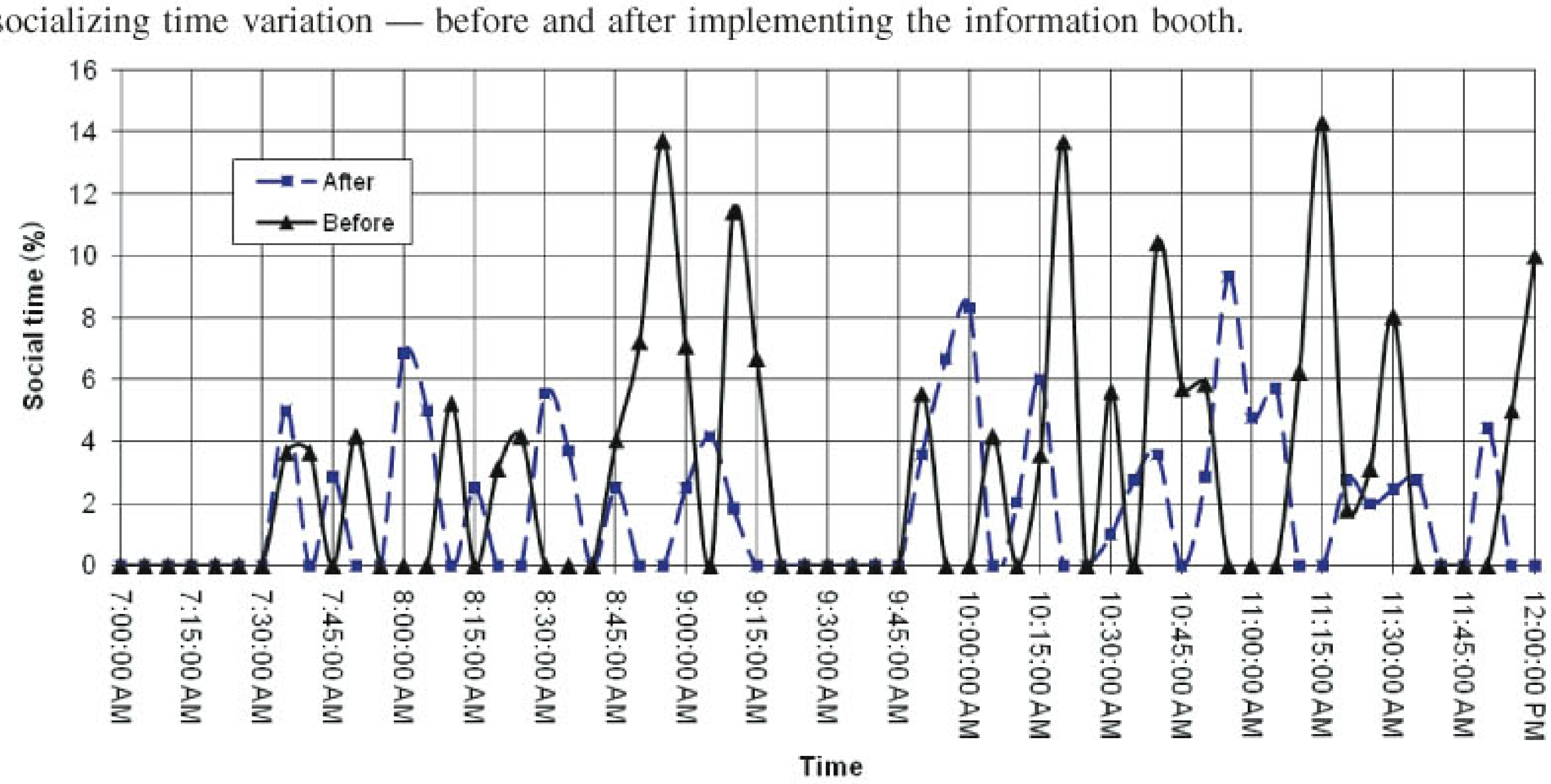


Table 1. Average output – before and after the information booth.

Lift No.	Output – before (m^2/(h worker))	Output – after (m^2/(h worker))	Percentage increase
2	1.46	1.46	0
3	1.12	1.19	6.25
4	0.84	0.99	17.86
5	—	1.29	—

Table 2. Output measurements with learning curve.

Lift No.	Output – before (m^2/(h worker))	Output – after (m^2/(h worker))	Predicted output (m^2/(h worker))	Difference	Net % increase
3	1.12	1.19	1.17	0.02	1.8
4	0.84	0.99	0.88	0.11	13.1

was erecting a wall formwork. These were pre-build form structures of "EFCO – Ply faced wall formwork". The size of a single form was 4.0 m × 2.2 m. Carpenters replaced the facing plywood boards of these structures from time to time based on the usage. The wall form was done in five lifts and Fig. 6 shows a cross section of the retaining wall (not to scale).

Tool time

Figure 7 and 8 show the average working time distribution of the observed construction project before and after the implementation of the information booth, respectively. Hewage and Ruwanpura (2006*b*) explained the definitions and detailed descriptions of the observed working time categories.

As shown in Fig. 7 and 8, a significant tool time gain was noted after the implementation of the information booth (45.95% to 54.96%). The average tool time (54.96%) is the highest observed by the authors in five construction projects from 2003 to 2007 for similar construction work. However, Choy and Ruwanpura (2006) argued that a single factor of influence cannot be attributed for productivity. They discussed the cumulative impact of the factors affecting productivity.

As discussed earlier, it is noted that the learning curve had an impact on the productivity gains. However, the learning curve did not have a considerable impact on the working efficiency (tool time). Productivity is a function of effectiveness and efficiency; where the learning curve has a considerable impact on effectiveness, not efficiency. As discussed, the workers were familiar with the operational sequence of the formwork before commencing the pilot study.

The tool time was increased by 9% as a result of reduced nontool time in certain categories; idling (excluding the assigned breaks and rest time) and moving. Some of the key observations are:

- With the proper early instructions and knowledge, workers reduced their idle time by 4%. Usually, workers were idle when the instructions and targets were not clear.
- Moving (moving around the site) usually occurs when the workers were not motivated and not closely supervised (Hewage and Ruwanpura 2006*a*). After implementing the information booth, the workers were provided clear instructions with expected time lines in advance of commencing the work.
- As expected, materials searching time did not change much even though the efficiency increased. One might expect that with improved efficiency, the worker would need more materials to work with, yet only a slight increase in material searching was noted (about 0.25% increased).
- Tools searching time was reduced by about 1.5%. After the implementation of the information booth workers generally picked up the necessary tools before starting the work based on the instructions given showing the locations.
- Instructions time was slightly increased because the information booth encouraged the workers to request necessary technical information before commencing work, thus improving the motivation for two-way communication than one-way communication (foreman to workers). The site foreman became more available and worked more than 90% of the total working time in the actual working area. The average instruction time noted in other construction sites was about 2.8% (Hewage and Ruwanpura 2006*a*)

A detailed working time analysis is presented in Figs. 9, 10, 11, and 12 for tool time, idle time, materials searching time, and socializing.

The most significant tool time variation noted in Fig. 9 was from 0715 to 0915 where the tool time was considerably higher after implementing the information booth. Before 0715 the workers were collecting the required tools and equipment from a central site trailer. The formal activities of the information booth had usually been completed by 0705.

Before implementing the information booth the workers were not exactly sure what the targets were. Much of the first hour was spent moving around the site or idling (0700 to 0800). A sudden tool time increase was observed just before the coffee break where the workers rushed to finish certain elements of the work before the break.

Although the tool time was generally highest from 0930 to 1200 (after implementing the information booth), the effect of early instructions and (or) information was not that influential on tool time. Before the information booth, workers received on-site instructions from foremen about the work targets during the early hours of work. Workers had

Table 3. Workers' views – before and after the information booth.

Question	Before						After					
	Mean	Std. dev.	Max	Min.	Median	Mode	Mean	Std. dev.	Max	Min.	Median	Mode
Do you clearly know your daily work targets?	5.21	1.63	7	1	5.5	6	6.00	1.18	7	3	6	6
Do you clearly know your weekly and (or) monthly work targets?	4.93	1.21	7	3	5.0	4	5.45	1.21	7	3	6	6
Generally, are you satisfied with the clarity of instructions?	5.36	1.28	7	2	5.5	6	5.73	1.42	7	3	6	7
Are you satisfied with the technical information you are getting?	5.07	1.33	7	2	5.0	5	5.73	1.27	7	3	6	6
Are you satisfied with the safety information you are getting?	5.43	1.34	7	2	5.5	5	6.00	1.34	7	3	6	7
Do you have a clear idea about the final output (number of levels, shape, and appearance) of your project?	5.07	1.21	7	3	5.0	6	5.91	1.38	7	3	6	7

nearly the same field instructions by 0930 in both cases: before and after the information booth. It should also be noted that the workers had an informal discussion with their lead workers and foremen during the coffee break – a time when missing information/instructions are usually discussed.

Figure 10 shows the idle time variation with the implementation of the information booth. After the information booth, idle time was almost zero until 0745 About 5% of the idle time was observed during this period prior to the use of the information booth. After the information booth, the idle time was considerably lower throughout the day except in a few instances. Idle time has a relationship to the physical fatigue of construction workers. The cyclic nature of idle time peaks is due to the physical fatigue caused by the very nature of construction work. Before the information booth, the idle time peaked every 10 to 15 min. These peaks were considerably higher than the idle time peaks after using the information booth. This was attributed to the early instructions received via the information booth.

Figure 11 shows the materials searching time comparison before and after the implementation of the information booth. The average time spent on material seeking did not change significantly because of the information booth. However, high peaks of material searching can be observed in Fig. 11 before the information booth. It seems workers planned their material needs in advance after the implementation of the information booth. High materials searching time leads to other nonproductive activities such as socializing, moving, and idling (Hewage and Ruwanpura 2006*a*).

Figure 12 shows socializing time comparison with the implementation of the information booth. As mentioned, socializing time decreased from 3.31% to 2.02% after the implementation of the information booth. Usually, workers tended to socialize as they were moving around the site, looking for materials, and idling. When these influencing categories were low, socializing time was also reduced.

Productivity improvements

The wall form was constructed in five lifts and the output information was collected accordingly (Fig. 6). The company completed the construction of the first lift and a part of the second lift before the start of the pilot project observations. Output information for the fifth lift was available only after the implementation of the booth since the fifth lift started during the information booth pilot test.

The most difficult position to install the formwork was lift four. The fifth lift had access from the top of the excavation area (workers could walk and access the form from the top of retaining wall in lift five). The third and fourth lift operations were totally handled by a crane and workers on scaffoldings. The easiest was the first and second lifts where the workers could work on the ground. Table 1 shows the average output for each lift before and after the implementation of the information booth.

As shown in Table 1, a significant improvement in output can be observed after the information booth. These comparable productivity figures are for the second, third, and fourth lifts. However, the information booth had only a slight influence on the second lift as the workers completed the second lift 2 days after the information booth was imple-

Fig. 13. Information booth for future construction projects.

mented. The third and fourth lifts were completed during the pilot study period. A productivity increase of 0.07 m^2/(h worker) and 0.15 m^2/(h worker) was determined for the third and fourth lifts, respectively.

However, according to the company's experience of a learning curve factor of 0.95 in every week; it is possible to modify Table 1 by combining the learning curve (Thomas et al. 1986) effects (Table 2).

According to Table 2, there was a 1.8% and 13.1% increase in output by considering the learning curve effect based on the company's previous experiences. However, the company did not have any empirical data to prove the constant rate of learning curve factor on formwork. As mentioned, Thomas et al. (1986) concluded that the learning rate is not necessarily a constant value as predicted by the company.

Worker satisfaction

The workers' views regarding on-site communication, instructions, quality and clarity of technical information, and their knowledge about the project (before and after the information booth) are in Table 3.

Workers satisfaction increased in all the categories related to on-site information, i.e., daily work targets, monthly and (or) weekly targets, clarity of instructions, technical information, safety information, and ultimate output of the work, after the addition of the information booth. Worker satisfaction with the knowledge of the final output and (or) appearance had the most significant change (0.84 on a 1 to 7 Likert scale).

Better project planning by the foreman

The researchers noted that the foreman's efforts to get ready for the next day's tool box meeting had considerably improved. The foreman verbally expressed his satisfaction with the information booth as it had enabled him to prepare, plan, and deliver the instructions clearly to the workers. This is a very significant subjective improvement for productivity and look-ahead planning although it was not possible to quantitatively measure the impact of the foreman's efforts as a result of the information booth.

Both the information booth (the technology) and improvements in work processes (with the information booth) such as more supervision time, fewer accidents, and awareness of material and tool availabilities contributed to the positive results discussed above.

Future of the information booth

Based on the views of both managers and workers, the initial concept of the information booth was fine-tuned with some additional items such as a rugged printer, a camera, and many other tools (Silva et al. 2008). Figure 13 consists of the components of a proposed information booth that could be used for future construction projects. All the devices used in the booth need to be rugged components, suited for the open environment of a construction site. Silva et al. (2008) outlined the integrated technological framework using the modified version of the information booth.

Research limitations

The research project described in this paper has the following limitations.

- As explained, the researchers made the best possible efforts to keep other influencing factors to construction productivity and efficiency unchanged during the pilot study period. However, researchers accept a certain degree of influence on the results due to factors such as temperature, learning curve, type of work, change orders, interruptions, material availabilities, and workers' physical strength.

- The developed conceptual IT framework was based primarily on the opinions and expectations of the construction workers in Calgary. It may be necessary to fine-tune the proposed framework for other locations by considering the company, project, and worker needs. As outlined by Silva et al. (2008), it is planned to extend pilot studies with the new version of the information booth for many construction project sites within Calgary and outside of Calgary.
- The information booth is a device whose success is dependent on continuous updates based on the specific needs of each construction site.

Conclusion

Use of information technology to overcome communication issues is quite limited in the construction industry. After a comprehensive analysis of the communication needs of the construction industry, an IT-based communication framework was proposed. One of the key components in this framework was the information booth. The main focus of the information booth was to transfer all the necessary information from all the project stakeholders to the on-site operational level.

The information booth has been pilot tested in actual construction settings. The impact of the information booth on regular site operations has been observed, documented, and analyzed. The researchers overcame many challenges to conduct a pilot study on information technologies in construction. The construction industry is known for resistance to technological changes. However, the pilot study was a success. The information booth has significantly increased efficiency, productivity, and worker satisfaction. Construction productivity on the wall formwork was increased by 0.07 m^2/(h worker) and 0.15 m^2/(h worker) on the third and fourth lifts of a wall, respectively. The tool time (efficiency) was increased by 9%. As a result of increased tool time, idle, moving, and socializing times were reduced by 4%, 3%, and 1%, respectively. Construction workers expressed their satisfaction over the information and communication processes and (or) standards developed with the information booth (over 12% satisfaction improvement). All the construction companies participating in the research project were positive about deploying the information booth in their future construction projects. The information booth also pushed the foreman to better pre-plan the construction activities and to communicate work expectations, targets, and other work related aspects clearly and visually.

The pilot study of the information booth has proven that the careful and rational use of information technologies in construction projects can increase productivity, efficiency, and worker satisfaction. Successful testing of the concept of the information booth and its applications has also led to the development of other integrated technological solutions for the construction industry.

Acknowledgements

The authors wish to acknowledge the support and funding for this research project provided by CANA, PCL, Ellis Don, Graham, Ledcor, Revay & Associates, Stuart Olson, the Canadian Construction Research Board, the Calgary Construction Association, and the Natural Sciences and Engineering Research Council of Canada under their Collaborative Research and Development Grant No. CRDPJ 299392-03 and CRDPJ 341047-06.

References

Abduh, M., and Skibniewski, M.J. 2004. Electronic networking technologies in construction. Journal of Construction Research, **5**(1): 17–42. doi:10.1142/S1609945104000036.

Allen, D. 2004. Establishing communications; vital key to success [online]. U.S. Army Signal Centre. Available from http://www.findarticles.com/p/articles/mi_m0PAA/is_4_28/ai_n6118581 [cited 6 March 2007].

Baldwin, J.R., and Sabourin, D. 2002. Impact of the adoption of advanced ICTs on firm performance in the Canadian manufacturing sector. Statistics Canada, Ottawa: Micro-Economic Analysis Division. (11F0019MIE No. 174)

Bateman, T.S., and Snell, S.A. 1999. Management: Building competitive advantage. 4th ed. McGraw-Hill, London. .

Bowden, S., Dorr, A., Thorpe, T., and Anumba, C. 2006. Mobile ICT support for construction process improvement. Automation in Construction, **15**(5): 664–676. doi:10.1016/j.autcon.2005.08.004.

Brandon, P. 2000. Construction IT: forward to what? Implementing IT to obtain a competitive advantage in the 21st century. *In* Proceedings of the International Conference on Construction Information Technology: 2000 (INCITE 2000), Hong Kong, 17–18 January 2000, Hong Kong Polytechnic University.

O'Brien, M.O., and Soufi, A.A. 1994. A survey of data communication in the UK construction industry. Construction Management and Economics, **12**(5): 457–465. doi:10.1080/01446199400000055.

Choy, E.C.Y. 2004. Modeling construction site productivity using situation-based simulation tool. M.Sc. thesis, University of Calgary, Calgary, Alta.

Choy, E., and Ruwanpura, J.Y. 2006. Modeling construction site productivity using situation-based modeling. Canadian Journal of Civil Engineering, **33**(12): 1585–1601. doi:10.1139/L06-088.

Da Silva, S.F.P. 2006. Developing best practices to improve construction productivity. M.Sc. dissertation, University of Calgary, Canada.

Dozzi, S.P., and AbouRizk, S.M. 1993. Productivity in Construction. Institute for Research in Construction, National Research Council Canada, Ottawa.

FIATECH. 2007. Fully integrated and automated technologies [online]. Available from www.fiatech.org [cited 12 November 2007].

Hewage, K.N., and Ruwanpura, J.Y. 2006*a*. Carpentry worker issues and efficiencies related to construction productivity in Alberta's commercial construction projects. Canadian Journal of Civil Engineering, **33**(8): 1075–1089. doi:10.1139/L06-050.

Hewage, K.N., and Ruwanpura, J.Y. 2006*b*. Technology adoptability and adaptability issues related to communication in Alberta commercial construction projects. Proceedings of the 1stst International Construction Specialty Conference, Canadian Society for Civil Engineering, 23–26 May 2006, Calgary, Alta.

Hewage, K.N., Ruwanpura, J.Y., and Jergeas, G. 2008. IT usage in Alberta's building construction projects: Current status and challenges. Automation in Construction. **17**(8): 940–947. doi:10.1016/j.autcon.2008.03.002.

Mohamed, S., and Stewart, R.A. 2003. An empirical investigation of users' perceptions of web-based communication on a construction project. Automation in Construction, **12**(1): 43–53. doi:10.1016/S0926-5805(02)00039-0.

Neil, J.M., and Knack, L.E. 1984. Predicting productivity. Transactions of the American Association of Cost Engineers, **3**(H3): 1–8.

Park, S. 2003. An analysis of the impact of information technology on the performance of construction contracting firms. Ph.D. thesis, Purdue University, Indiana.

Silva L.P., Hewage K.N., Ruwanpura J.Y., and Wirasinghe, U.G.D. 2008. Total information system integration in construction projects. *In* Proceedings of the 1st International Construction Specialty Conference. Canadian Society for Civil Engineering, Quebec City, Quebec, 10–13June 2008.

Thomas, H.R., Mathews, C.T., and Ward, J.G. 1986. Learning curve models of construction productivity. Journal of Construction Engineering and Management, **112**(2): 245–258. doi:10.1061/(ASCE)0733-9364(1986)112:2(245).