Incentive Reward Program for Reducing Construction Wastes

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Abstract: This paper presents a group-based incentive reward program (IRP) to encourage workers to minimize avoidable wastes of construction materials by rewarding them according to the amounts and values of materials they saved. Bar-code technique is used to facilitate effective management of construction materials. An experiment is conducted on a residential project and results from the experiment demonstrate the effectiveness of the IRP in motivating workers to reduce construction wastes. Discussions on the relationship between construction waste reduction and time and cost performances are also presented. Difficulties and challenges of applying IRP are also discussed.

INTRODUCTION

Construction waste is a serious environmental problem in many large cities. In Hong Kong, the quantity of construction and demolition (C&D) waste was about 656 cubic meters per day in 1984 and about 15,577 cubic meters per day by the end of 1998 (EPD 1999). As there are increasing demands on residential buildings in Hong Kong, a 13-year production program has been established by the Government in 1998, which has been rolled forward to produce an average of 50,000 flats in public sector and 35,000 flats in the private sector each year (HB 1999). So how to reduce construction waste is becoming even more important.

There have been many research efforts in construction waste control. For example, a study which investigated construction waste generated from public housing projects in Hong Kong was conducted in 1992 (Cheung *et al* 1993). Methods for construction waste minimization in

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Hong Kong were also discussed by Poon *et al* (1996). These waste minimization methods emphasize on using modern technologies in building construction, such as precast concrete, steel form and scaffold, drywall partition panel, etc. However, surveys show that local construction firms in Hong Kong feel it is expensive to use new machinery and automation (Ho 1997); most (68~85%) of local construction firms agree to adopt low-waste techniques only when they are demanded by the designers, the specifications, or the clients (Poon *et al* 1999). As a result, construction waste control in Hong Kong is still a major problem to be solved.

The objective of this paper is to present an on-site material management scheme by using an incentive reward program (IRP) to control and reduce construction wastes. The scheme is designed to encourage construction workers, who are directly involved in producing construction wastes, to reduce wastes by rewarding them based on the amounts and values of the materials they saved. The bar-coding technique is used to facilitate easy data recording and transfer.

ON-SITE CONSTRUCTION WASTES

Although there is no generally accepted definition, construction waste can be loosely defined as the debris of construction and demolition (C&D) (EPA 2000). Specifically, construction waste refers to solid waste containing no liquids and hazardous substances, largely inert waste, resulting from the process of construction of structures, including buildings of all types (both residential and nonresidential) as well as roads and bridges. Construction waste does not include cleanup materials contaminated with hazardous substances, friable asbestos-containing materials, lead, waste paints, solvents, sealers, adhesives, living garbage, furniture, appliances, or similar materials.

Although it is difficult to give exact figures of construction wastes generated on a construction site, it is estimated that as much as 10% construction materials are wasted (Stone 1983). Data obtained from specialty contractors in USA, UK, China Mainland, Brazil, Korea and Hong Kong present a comparison of construction wastes generated from construction industries in these countries/regions, which is displayed in Table 1.

Table 1. Average wastage rate of construction materials on site

Material	Average wastage (%)					
	USA (Schuette and Liska 1994)	**UK** (Skoyles 1992, and Frics 1996)	**Mainland, P R China** (Zhu 1996)	**Brazil** (Bossink and Brouwers 1996)	**Seoul** (Seo and Hwang 1999)	**Hong Kong** (Site surveys)
Brick/Block	3.5	4.5	2.0	17.5	3.0	No available
Concrete	7.5	2.5	2.5	7.0	1.5	6.7
Drywall	7.5	5.0	Not specified	Not specified	Not specified	9.0
Formwork	10.0	Not specified	7.5	Not specified	16.7	4.6
Glass	Not specified	Not specified	0.8	Not specified	6.0	2.3
Mortar	3.5	Not specified	5.0	46.0	0.3	3.2
Nail	5.0	Not specified	Not specified	Not specified	Not specified	Not available
Rebar	5.0	Not specified	3.0	21.0	Not specified	8.0
Tile	6.5	5.0	Not specified	8.0	2.5	6.3
Wallpaper	10.0	Not specified	Not specified	Not specified	11.0	No available
Wood	16.5	6.0	Not specified	32.0	13.0	45.0

According to our site surveys and literatures review, construction waste generated from public & private housing projects mainly includes wastage of cement, concrete rubbles, drywall scraps, wood scraps, rebar scraps, concrete block scraps, plastic conduit tailings, material packing and container, nails and some other unused materials. For example, a site survey of public housing project shows (Table 2) that different construction processes can generate different construction waste.

Table 2. Construction Waste Generated from Construction Processes

Construction Process	Construction Waste								
	Concrete rubble	Drywall scrap	Block scrap	Cement wastage	Wood scrap	Rebar tailing	Nail	Plastic conduit tailing	Material packing & container
Fix wall rebar						✓		✓	
Place precast facade									✓
Place wall form					✓	✓*			
Concrete wall	✓			✓					✓
Strip wall form	✓								
Place precast slab									
Fix timber slab				✓	✓		✓		
Fix slab rebar						✓		✓	
Concrete slab	✓			✓					✓
Fix drywall		✓							
Bond block			✓						

Note: * when through-wall sleeve can't be fixed easily, wall rebar will be cut.

It has been observed that the main cause of material wastes is due to incorrect or careless use of materials by workers on sites. These kinds of wastes can be avoided or reduced if workers are motivated to be more conscious and responsible.

AVOIDABLE MATERIAL WASTES CAUSED BY WORKERS

Workers are executors of construction operations. Our site surveys show that workers' attitude towards construction operations and materials can make a significant difference to the amount of construction wastes generated. Without careful control and rewarding systems, construction workers may become careless in handling construction materials. As a result, reusable reinforcement bars, discarded half-bags of cement, discarded nails and timber pieces are often seen on the sites. Table 3 gives an example of avoidable wastes caused by workers in public housing projects in Hong Kong.

Table 3. Avoidable Wastes Caused by Workers in Public Housing Projects in HK

Construction Process	Avoidable Wastes Caused by Workers
Fix wall rebar	Extra processed rebar, arbitrarily cut rebar, abandoned rebar tailing, etc.
Place precast facade	Damaged facade board, broken scraps during erection.
Place wall form	Arbitrarily cut & drilled plywood board, abandoned plywood board.
Concrete wall	Left-over mixed concrete, excess concreting, etc.
Strip wall form	Damaged forms.
Place precast slab	Damaged slab boards, broken scraps during erection.
Fix timber slab	Arbitrarily cut & drilled plywood boards, abandoned plywood boards.
Fix slab rebar	Extra processed rebar, arbitrarily cut rebar, abandoned rebar tailing, etc.
Concrete slab	Left-over mixed concrete, excessive concreting, etc.
Fix drywall	Arbitrarily cut drywall board, damaged drywall board, broken scraps during erection.
Bond block	Extra mortar, extra delivered blocks, cut & abandoned blocks, etc.

Our site surveys indicate that skill, enthusiasm, and collectivism are the main factors affecting the amounts of wastes produced by workers. Among these three factors, workers' attitude toward their work, including their enthusiasm and collectivism, is regarded as the most important in terms of waste generation, while their skill levels is relatively less important. In other words, if workers do not take care of what they are doing then more materials will be wasted. So it is important to establish an on-site construction material management system to encourage construction workers to use materials carefully, and to enhance their enthusiasm and collectivism by rewarding them based on their good performances in saving materials through reducing operational mistakes, returning unused materials for reuse or recycle, etc.

INCENTIVE REWARD PROGRAM

Our site surveys show that construction materials are taken from the storages on site without effective control, and placed with poor organization, especially in large projects or during urgent construction processes. The construction material control system to be established aims to provide an effective tool for the project manager to manage on-site materials, and to motivate workers to reduce material wastes into its minimum.

Research on the relationship between motivation and productivity in the construction industry has been conducted over the last 40 years (Olomolaiye *et al* 1998). The relationship between motivation and productivity is summarized as that productivity is dependent upon motivation, and motivation is in turn dependent on productivity (Warren 1989). A comparison of labor productivity for masonry activities from seven countries, including Australia, Canada, England, Finland, Scotland, Sweden and the United States, reveals that there is little difference in productivity of the seven countries despite significant differences in labor practices, and the principal difference is the management influence (Thomas, *et al* 1992). This viewpoint is replenished with a case study focusing on the impact of material management on productivity, which shows that ineffective material management could incur losses of productivity (Thomas, *et al* 1990). On the other hand, a series of comparative evaluations of labor productivity rates amongst French, German and UK construction contractors indicate that German workers are likely to be highly motivated (because they are high paid and regarded as on a par with people doing intellectual and scientific work), and hence, more productive (Proverbs, *et al* 1998). All these research results reinforce that higher motivation brings higher productivity.

According to Maslow's motivation theory (Warren 1989), beyond their safety and health needs, workers require both emotional and financial rewards for exercising self-discipline in handling construction materials. There are many forms of rewards and punishments for worker's performance measure (Nelson 1994). Among these positive and negative rewarding (punishing) methods, some have been used on construction sites. For example, the use of special motivational program, and financial incentive programs (FIP) have been reported (Laufer and Jenkins 1983, Liska and Snell 1993, Carberry 1996, and Olomolaiye 1998). The FIP is an important method for motivating workers, and it has been proved to be effective in improving quality and reducing project time and cost (Laufer and Jenkins 1983). Furthermore, the FIP has been widely accepted as a performance-dependent monetary reward system in the construction industry (Merchant 1997). So the IRP developed in this study is designed based on the principle of FIP, in order to meet the demand of on-site construction material management.

Fairness is an important consideration in designing the IRP; less fairness or unfairness would result in the failure of the IRP and may even have adverse effect on a construction project. Before the IRP is implemented, its fairness should be examined carefully. There are two aspects of fairness in the IRP; one is the fairness to workers, another is its fairness to the firm. The fairness to the firm is easy to investigate. Because the IRP relates to the amount of construction materials consumed on site and if the overall amounts of construction wastes are reduced, then the firm will be benefited. So the firm should share the benefits (saved money) with the contributors - workers.

The fairness of the IRP to workers is different. Workers are normally organized into gangs or groups according to their trades or types of work. Material is normally shared within the group. If an amount of material waste is detected, who should be punished, or, if there is a reduction of waste, who should be rewarded: the person who is responsible for shifting material from the storage, or the leader of the group? Based on discussions with the project managers and workers involved in the projects we surveyed, we decided to adopt a group-based IRP. In the group-based IRP, members of the group will be rewarded or punished equally should there be any reduction and increase of material wastes. Group-based rewards provide a common goal for group members and encourage cooperation among members to achieve a higher performance, and it avoids the difficulty in determining individual's contribution (Laufer and Jenkins 1983, Merchant 1997).

In the group-based IRP, each working group has a group leader who is responsible for withdrawing all the materials needed by his group from the storage keeper. The storage keeper records the amount of materials taken by each group. When a group finishes its work, the group leader is also responsible for arranging any unused materials to be returned back to the storage keeper for updating the records.

Once a construction operation is completed, the project manager can measure the amount of material waste reduced or increased by comparing the actual amount of material used by the group with the estimated amount. The actual amount of material used is recorded by the storage keeper, while the estimated amount of material is prepared by the contractor's quantity surveyors. The estimated amount includes a percentage which is considered as a normal amount of waste on site. The percentage is determined based on the contractor's experience from the levels of wastes in past projects.

For a particular type of material i, the performance of group j in terms of material wastage can be measured using set 1.

$$\Delta Q^i(j) = Q^i{}_{estimated}(j) - (Q^i{}_{delivered}(j) - Q^i{}_{returned}(j)) \tag{1}$$

Where $\Delta Q^i(j)$ is the extra amount of material i saved (if the amount is a positive value) or wasted (if the amount is a negative value) by group j; $Q^i{}_{delivered}(j)$ denotes the total quantity of material i requested by group j; and $Q^i{}_{estimated}(j)$ denotes the estimated quantity which includes the statistic amount of normal wastage. The value of $Q^i_{estimated}(j)$ has to be carefully decided according to the circumstances of construction projects and previous experience (Schuette and Liska 1994, CIOB 1997). The $Q^i_{unused}(j)$ is the quantity of unused construction materials returned to the storage by group *j*.

At the end of the project, the overall performance of group *j* can be measured by set 2.

$$C^i(j) = \sum_{n} \Delta Q^i(j) \bullet P_i \qquad (2)$$

Where $C^i(j)$ denotes the total amount of material *i* saved (if $C^i(j)$ is positive) or wasted (if $C^i(j)$ is negative) by group *j*; *n* is the total number of tasks in the project that need to use material *i*; and P_i is the price for material *i*.

The contracting company has to develop a policy to specify how the company shares with workers the costs/benefits incurred from the reduction or increase of material wastes. For example, the company may decide that workers should share 40% of the $C^i(j)$. In other words, the company will give back 40% of the $C^i(j)$ to workers as rewards. The rewards can be positive if the value of $C^i(j)$ is positive; and it can be negative (penalties) if the value of $C^i(j)$ is negative.

IMPLEMENTAION OF IRP USING BAR-CODING TECHNOLOGY

Bar-code applications have been introduced to the construction industry since 1987 for material management, plant and tool control (Bell and McCullouch 1988, McCullouch and Lueprasert 1995, Stukhart 1995, Bernold 1991). The primary function of the bar-code system is to provide instant and up-to-date information of quantities of materials exchanged between the storage keep and the group leaders. Specifically, the bar-code system can provide the following functions:

- automatically tracking real-time data of construction materials on the site;
- automatically recording historical data of construction materials consumed in the project;
- automatically monitoring materials consumption of working groups;
- automatically transferring real-time data of materials to head office via Intranet and/or Internet.

The architecture of the bar-code system used in this implementation is illustrated in Figure 1.

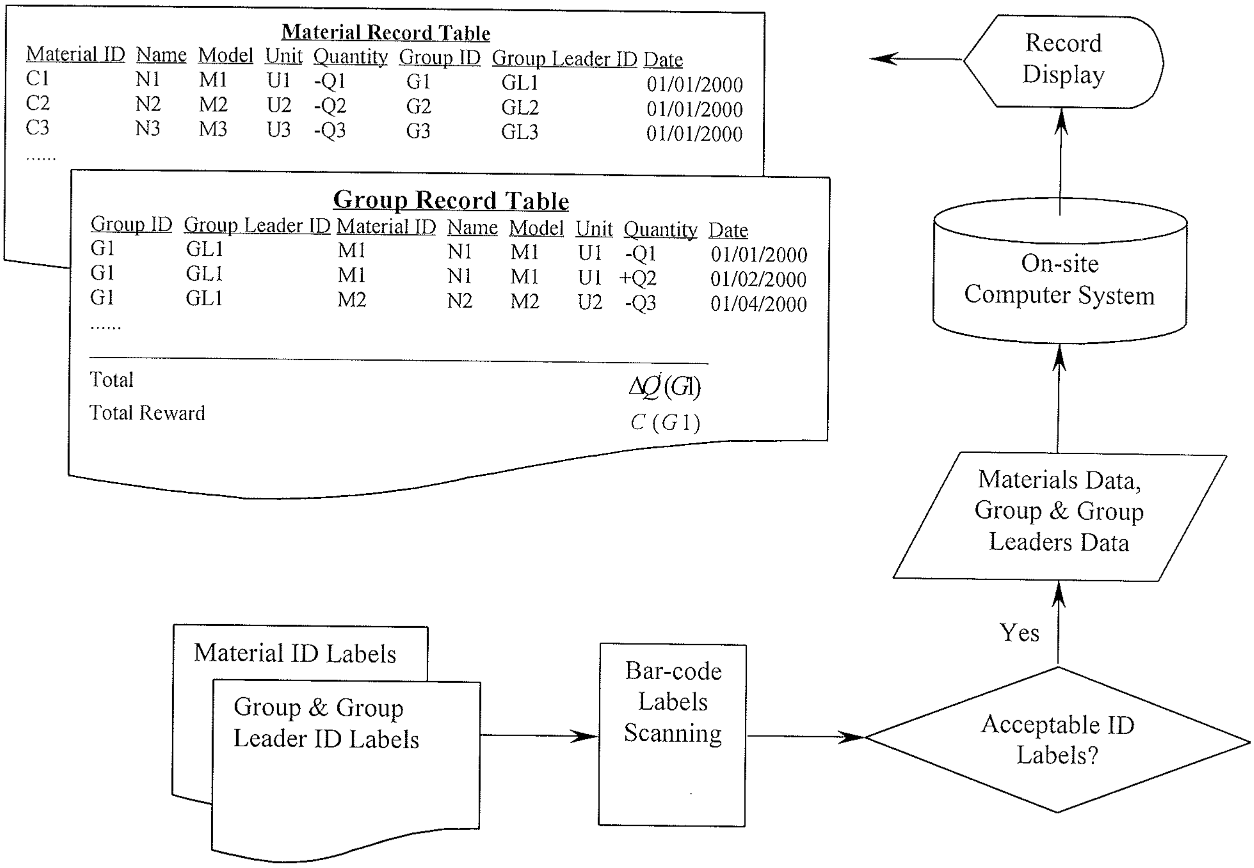


Figure 1. Data Flowchart of the bar-code system for group-based IRP

From Figure 1, it can be seen that when the group leader goes to the storage to withdraw new materials or return surplus materials, the storage keeper scans the barcode labels for the materials as well as the ID card of the group, so that the amounts of materials taken or returned by the group are registered in the database. Based on the amounts of materials initially ordered according to the estimated requirements, and the materials used by working groups, the computer system can calculate the value of $C^i(j)$ for each group j. Barcodes are given to each item (if it is big, eg. door, window etc), or each pack (if the items are small, eg. pack of nails, bolts and nuts).

The bar-code adopted for materials is the Code 128 symbology (Stukhart 1995), and the codes are designed to represent Material, Model and Quantity. For example, the code *0001-19-1* represents "plywood formwork - 19 mm thick -1 square meters", as shown in Figure 2.

Because bar-code labels can be easily damaged during transportation and items of construction materials are cumbersome for the storage keeper to scan the barcode labels if they are adhered onto the items/packs, we prepared a handbook of bar-code labels for all the construction materials used on site. This handbook contains all the barcodes and is maintained and used by the material storage keeper.

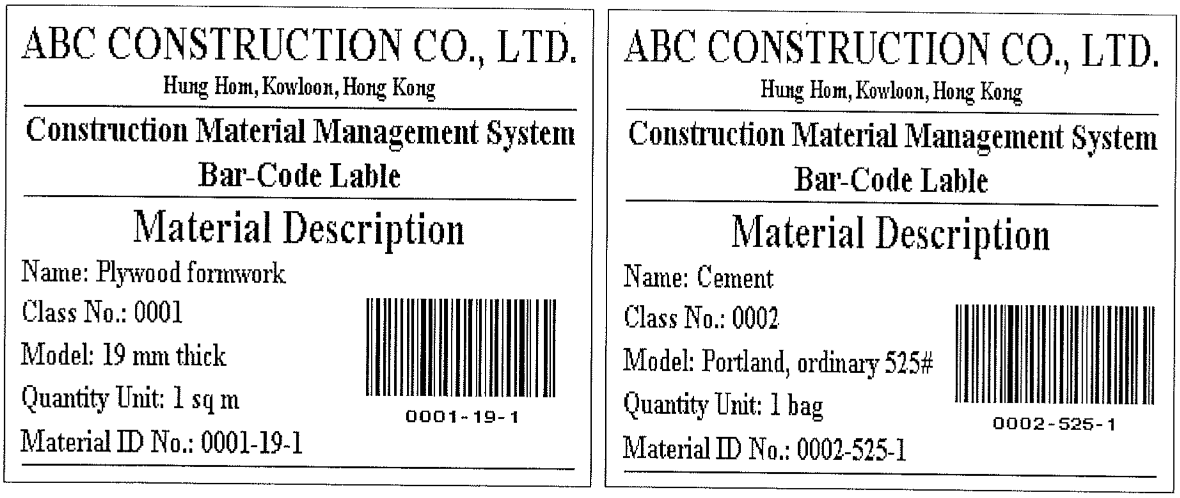
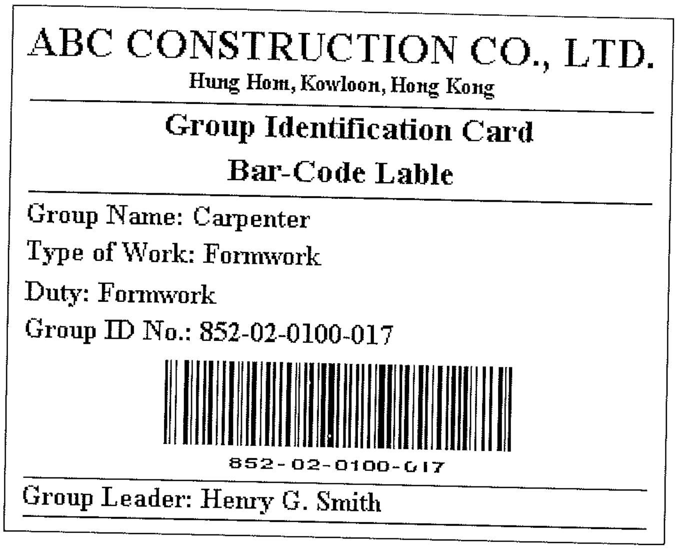


Figure 2. Sample barcodes for construction materials

For each working group, an identification card is issued to the group leader, who is responsible for withdrawing and returning construction materials. Figure 3 gives a sample identification card for a working group.


ABC CONSTRUCTION CO., LTD.
Hung Hom, Kowloon, Hong Kong

Group Identification Card
Bar-Code Lable

Group Name: Carpenter
Type of Work: Formwork
Duty: Formwork
Group ID No.: 852-02-0100-017

852-02-0100-017

Group Leader: Henry G. Smith

Figure 3. ID Card for the Carpenter group

The barcode of the group represents the group and its leader. For example, ID number *852-02-0100-017* represents "Carpenter group 852 and its leader's staff ID number is 02-0100-017", as shown in Figure 3. By scanning the barcodes for the materials and the group, the computer system keeps records of materials used or returned by the group. These records are then used to calculate the reduction and increase of material wastes generated by the group.

EXPERIMENTAL RESULTS

A public housing project in Hong Kong was selected to experiment the group-based IRP. The project involved constructing two identical 34-storey residential blocks using a 6-day cycle. The 6-day cycle included nine major activities undertaken by nine working groups. The two blocks were constructed simultaneously by two teams of workers, each team having nine working groups with equal numbers of workers to carry out the 6-day cycle construction method. We labeled the two teams as Team A and Team B. For the purpose of comparison, Team A did not adopt the group-based IRP during their operations, while Team B implemented the IRP with our advice and support.

(insert Table 4 and 5)

The experiment has been conducted over three months. Results from Team A and B during the three months are listed in Table 4 and 5. The first column of the tables is the list of major materials used in the 6-day cycle. The second column is the unit of the materials; the third column contains the group names and their tasks. Columns 4-6 list estimated quantities of materials, quantities of materials delivered to groups, and quantities returned by groups. Column 8 lists the prices of materials, while Column 7 and 9 list results of calculations based on sets 1 and 2. From the experimental results, it can be observed that throughout the three months, Team A consistently wasted more construction materials than Team B, because workers in Team A did not see the benefits of reducing wastes. Therefore, by the end of three months, Team A has wasted additional amounts of construction materials valued at HK$747948. On contrast, Team B has made a substantial saving of HK$703545, indicating that the group-based IRP had effectively motivated workers in Team B in reducing avoidable wastes. These results convinced us that the group-based IRP is effective in reducing construction wastes.

Although experimental results demonstrated the obvious strength of the group-based IRP in reducing wastage of construction materials, there has been a concern from the senior management of the contracting company in using the group-based IRP. The concern was the fear that workers might jerry-build in order to save materials. As the IRP does not directly relate itself to the quality of work. Therefore, the management felt that there is a need to investigate how to combine the time and quality performances of workers with the IRP when deciding the amounts of rewards to workers.

Difficulties have been identified during implementing the IRP on site. First, because the bar-code system can only recognize materials that have the standard quantity and does not automatically accept returned bits and pieces, quantities of the returned materials have to be assessed by the storage keeper and be manually entered into the computer system. This can potentially bring inaccuracies into the system. Second, as different groups may withdraw same materials, misunderstanding and conflicts between groups may occur if materials of one group are moved or mistakenly used by members of other groups. This problem will be intensified in situations with congested working spaces. These problems need to be resolved before the group-based IRP is fully accepted and endorsed by the industry.

CONCLUSIONS

This paper presents a group-based IRP which encourages workers to reducing avoidable wastes of construction materials on site. The IRP is based on the principle of motivating workers through giving them performance-based financial rewards. In addition, the paper introduces the use of a bar-code system to register the flow of materials so that performances of working groups in terms of material wastage can be easily measured. Results obtained from experimenting the IRP on a residential project indicate that the group-based IRP is effective in motivating workers to cut down avoidable wastes. Discussions on the difficulties of using IRP as well as its relationship to quality and time performances are also provided.

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APPENDIX. REFERENCES

Bell, L. C., and McCullouch, B. G. (1988) Bar Code Application in Construction. *Journal of Construction Engineering and Management*. ASCE. Vol. 114, No. 2. 263-278.

Bernold, L. E. (1991) Testing Bar-Code Technology in Construction Environment. *Journal of Construction Engineering and Management*. ASCE. Vol. 116, No. 4. 643-655.

Bossink, B. A. G., and Brouwers, H. J. H. (1996) Construction Waste: Quantification and Source Evaluation. *Journal of Construction Engineering and Management*. ASCE. Vol. 122, No. 1. 55-60.

Carberry, E. (1996) Assessing ESOPs. *Journal of Management in Engineering*. ASCE. Vol. 12, No. 5. 17-19.

Cheung, C. M., Wong, K. W., Poon, C. S., Fan, C. N., and Cheung, A. C. (1993) *Reduction of Construction Waste: Final Report*. Department of BRE and CSE of the Hong Kong Polytechnic University and The Hong Kong Construction Association Ltd..

CIOB (1997). *Code of Estimating Practice (6th edition)*. The Chartered Institute of Building. Longman. England.

EPA (2000) *EPA Region 9 Solid Waste Program: Construction and Demolition (C&D) Debris*. Available at http://www.epa.gov/region09/waste/solid/debris.htm.

EPD, Government of the HKSAR (1999) *Monitoring of Solid Waste in Hong Kong 1997*. Available at *http://www.info.gov.hk/epd/E/pub/sw-rep/Toc.htm*.

EPD, Government of the HKSAR (1999) *Solid Waste Statistics 1998 Updates*. Available at *http://www.info.gov.hk/epd/E/pub/sw-rep/98update/Index.htm*.

Frics, J. W. (1996) *Estimating for Building and Civil Engineering Works (9th Ed.)*. Butterworth Heinemann Ltd. Oxford.

HB, Government of the HKSAR (2000). *Hong Kong Fact Sheet - Housing (1999)*. Available at *http://www.info.gov.hk/hkfacts/housing.pdf*.

Ho, L. (1997) *Human resources planning strategies of the Hong Kong construction industry*. Thesis of MBA. Department of Management, Hong Kong Polytechnic University.

Liska, R. W., and Snell, B. (1993) Financial Incentive Programs for Average-Size Construction Firm. *Journal of Construction Engineering and Management*. ASCE. Vol. 118, No. 4. 667-676.

Merchant, K. A. (1997) *Modern Management Control Systems: Text and Cases*. Prentice-Hall, Inc. New Jersey.

McCullouch, B. G., and Lueprasert, K. (1995) 2D Bar-Code Applications in Construction. *Journal of Construction Engineering and Management*. ASCE. Vol. 120, No. 4. 739-753.

Nelson, B. (1994) *1001 Ways to Reward Employees*. Workman. New York.

Olomolaiye, P. O., Jayawardane, A. K. W., and Harris, F. C. (1998) *Construction Productivity Management*. The Chartered Institute of Building. Addison Wesley Longman Limited.

Poon, C. S., Xu, Y., and Cheung, C.M. (1996) Building Waste Minimization in Hong Kong Construction Industry. *Journal of Solid Waste Technology and Management*. Vol. 23, No. 2. 111-117.

Poon, C. S., and Ng, L. H. (1999) The Use of Modern Building Technologies for Waste Minimization in Hong Kong. *Proceeding of International Conference on Urban Pollution Control Technology (eds.* Poon, C. S., and Li, X. Z.*)*. The Hong Kong Polytechnic University. Hong Kong. 413-419.

Proverbs, D. G., Holt, G. D., and Olomolaiye, P. O. (1998) A comparative evaluation of reinforcement fixing productivity rates amongst French, German and UK construction contractors. *Engineering, Construction and Architectural Management.* Vol. 5, No. 4, 350-358.

Seo, S., and Hwang, Y. (1999) An Estimation of Construction and Demolition Debris in Seoul, Korea: Waste Amount, Type, and Estimation Model. *Journal of the Air & Waste Management Association*. Vol. 49, August. 980-985.

Schuette, S. D., and Liska, R. W. (1994) *Building Construction Estimating*. McGraw-Hill, Inc. New York.

Skoyles, J. R. (1992) An approach to reducing materials waste on site. *The Practice of Site Management (Volume 4)* (*Ed.* Harlow, P. A.) The Chartered Institute of Building. Englemere, UK.

Stone, P. A. (1983) *Building Economy (3rd Ed.)*. Pergamon Press. England.

Stukhart, G. (1995) *Construction Materials Management*. Marcel Dekker, Inc., New York.

Thomas, H. R., Sanvido, V. E., and Sanders, S. R. (1990) Impact of Material Management on Productivity - A Case Study. *Journal of Construction Engineering and Management*, ASCE. Vol. 115, No. 3, 370-384.

Thomas, H. R., Sanders, S. R., and Bilal, S. (1992) Comparison of Labor Productivity. *Journal of Construction Engineering and Management*, ASCE. Vol. 118, No. 4, 635-650.

Warren, R. H. (1989) *Motivation and Productivity in the Construction Industry.* Van Nostrand Reinhold. New York.

Zhu, Z. (1996) Handbook of Building Construction Estimator. China Construction Industry Press. Beijing.

Table 4. Experimental Result without Group-based IRP (Team A)

Materials	Unit	Group							$C(j)$
		Name	Duty						
Rebar	ton	Steel bender	Fix wall rebar	1760.00	1795.20	0.00	-35.20	2271.31	-79950.11
			Fix slab rebar	1408.00	1425.60	0.00	-17.60	2271.31	-39975.06
Precast facade	set	Rigger	Place precast façade	1760.00	1760.00	0.00	0.00	3000.00	0.00
Precast slab	set		Place precast slab	9856.00	9856.00	0.00	0.00	1500.00	0.00
Cement	ton	Concretor	Concrete wall	31680.00	31715.20	0.00	-35.20	640.80	-22556.16
			Concrete slab	10560.00	10630.40	0.00	-70.40	640.80	-45112.32
		Plasterer	Fit up wall, ceiling & floor	15400.00	15554.00	0.00	-154.00	640.80	-98683.20
Sand	cubic meter	Concretor	Concrete wall	26928.00	27280.00	0.00	-352.00	57.04	-20078.08
			Concrete slab	10560.00	11264.00	0.00	-704.00	57.04	-40156.16
		Plasterer	Fit up wall, ceiling & floor	24024.00	24670.80	0.00	-646.80	57.04	-36893.47
Cobblestone	cubic meter	Concretor	Concrete wall	26752.00	27456.00	0.00	-704.00	58.30	-41043.20
			Concrete slab	10560.00	11264.00	0.00	-704.00	58.30	-41043.20
Hydrated lime	ton	Plasterer	Fit up wall, ceiling & floor	9394.00	9424.80	0.00	-30.80	464.00	-14291.20
Plywood formwork	square meter	Carpenter	Fix timber slab form	26400.00	27280.00	0.00	-880.00	57.20	-50336.00
Nail	bag		Fix timber slab form	1760.00	2640.00	0.00	-880.00	50.10	-44088.00
Drywall board	square meter	Rigger	Install wall board	9460.00	9900.00	0.00	-440.00	164.00	-72160.00
Block	10000 blocks	Bricklayer	Bond masonry wall	2.20	2.75	0.00	-0.55	7296.12	-4012.87
Embedded plastic conduit	meter	Electrician	Concel conduit installation	18480.00	22000.00	0.00	-3520.00	1.05	-3696.00
Glass	square meter	Glazier	Install window glass	8078.40	8448.00	0.00	-369.60	27.80	-10274.88
Paint	square meter	Painter	Fit up minor works	468.60	484.00	0.00	-15.40	25.00	-385.00
Wall tail	square meter	Plasterer	Fit up wall	22704.00	23760.00	0.00	-1056.00	34.00	-35904.00
Mosaic	square meter		Fit up wall and floor	10824.00	11352.00	0.00	-528.00	89.60	-47308.80
			Total($)						-747947.71

Table 5. Experimental Result with Group-based IRP (Team B)

Materials	Unit	Group							$C(j)$
		Group name	Duty						
Rebar	ton	Steel bender	Fix wall rebar	1760.00	1724.80	17.60	52.80	2271.31	119925.17
			Fix slab rebar	1408.00	1372.80	17.60	52.80	2271.31	119925.17
Precast facade	set	Rigger	Place precast façade	1760.00	1760.00	0.00	0.00	3000.00	0.00
Precast slab	set		Place precast slab	9856.00	9856.00	0.00	0.00	1500.00	0.00
Cement	ton	Concretor	Concrete wall	31680.00	31609.60	17.60	88.00	640.80	56390.40
			Concrete slab	10560.00	10454.40	17.60	123.20	640.80	78946.56
		Plasterer	Fit up wall, ceiling and floor	15400.00	15276.80	15.40	138.60	640.80	88814.88
Sand	cubic meter	Concretor	Concrete wall	26928.00	26576.00	105.60	457.60	57.04	26101.50
			Concrete slab	10560.00	10384.00	211.20	387.20	57.04	22085.89
		Plasterer	Fit up wall, ceiling and floor	24024.00	23870.00	123.20	277.20	57.04	15811.49
Cobblestone	cubic meter	Concretor	Concrete wall	26752.00	26576.00	246.40	422.40	58.30	24625.92
			Concrete slab	10560.00	10384.00	211.20	387.20	58.30	22573.76
Hydrated lime	ton	Plasterer	Fit up wall, ceiling and floor	9394.00	9332.40	3.08	64.68	464.00	30011.52
Plywood formwork	square meter	Carpenter	Fix timber slab form	26400.00	26048.00	140.80	492.80	57.20	28188.16
Nail	bag		Fix timber slab form	1760.00	1584.00	88.00	264.00	50.10	13226.40
Drywall board	square meter	Rigger	Install wall board	9460.00	9350.00	0.00	110.00	164.00	18040.00
Block	10000 blocks	Bricklayer	Bond masonry wall	2.20	2.15	0.22	0.28	7296.12	2006.43

Embedded plastic conduit	meter	Electrician	Concel conduit installation	18480.00	18004.80	176.00	651.20	1.05	683.76
Glass	square meter	Glazier	Install window glass	8078.40	7867.20	26.40	237.60	27.80	6605.28
Paint	square meter	Painter	Fit up minor works	468.60	462.00	2.20	8.80	25.00	220.00
Wall tail	square meter	Plasterer	Fit up wall	22704.00	22545.60	132.00	290.40	34.00	9873.60
Mosaic	square meter		Fit up wall and floor	10824.00	10718.40	132.00	237.60	89.60	21288.96
			Total($)						**705344.85**