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Factors affecting the appreciation generated through applying human factors/ergonomics (HFE) principles to systems of work

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ABSTRACT

This retrospective study examined the levels of appreciation (applause) given by clients to Human Factors/Ergonomic (HFE) specialists after they have modified the systems of work. Thirteen non-academic projects were chosen because the HFE interventions involved changed the way workers work at their workplaces. Companies involved range from multi-national corporations and military organizations with thousands of employees to small trading companies with less than 10 employees. In 5 cases the HFE recommendations were fully adopted and well appreciated. In 4 they were largely ignored and not appreciated, with partial adoption and some appreciation in the other 4 cases.

Three factors that predict appreciation were identified: (i) alignment between the benefits HFE can provide and the project's key performance indices; (ii) awareness of HFE among the client's senior management; and (iii) a team organization appropriate for applying HFE recommendations. Having an HFE specialist on the client's side can greatly increase levels of appreciation, but lack of such a specialist will not affect levels of appreciation. A clear contractual requirement for HFE intervention does not promote appreciation significantly, but its absence can greatly reduce levels of appreciation. These relationships are discussed using the Kano's model of quality. Means to generate greater appreciation of the benefits of HFE are discussed. Partial finding of this study was presented at the keynote address of the 1st Human Factors and Ergonomics Society of Philippines Conference held in Nov., 2012.

1. Introduction

1.1. What is system HFE and what do we mean by 'appreciation'?

Within the context of this paper, the term system HFE will be used to describe the application of HFE principles to change a system (or systems) of work. Such a broad definition would have covered almost all aspects of HFE and one could ask why another definition is necessary. The intention is to shift attention from specific HFE techniques or methodologies (e.g., anthropometry, usability validations, graphical user interface checklists, etc.) to the holistic impacts of HFE interventions. Dul has reported that HFE involves a unique combination of three characteristics: "(1) it takes a systems approach; (2) it is design driven; and (3) it focuses on two closely related outcomes: performance and well-being." (Quoted from Dul et al., 2012 p.377). Under the current definition, practicing system HFE will inevitably involve all three characteristics. Practicing system HFE is also consistent with principle of participatory ergonomics as suggested by Kogi which stresses on implementing HFE principles through users involvement and leading to some measurable improvement in productivity (2006). While both Dul and his colleagues' suggestions and Kogi's suggestions highlighted the need for improvement in performance (or productivity), this study focuses on another outcome which is the level of appreciation or applause to be given by a client to an HFE specialist after the implementation of a HFE intervention. In other words, we investigated whether the clients welcomed the implementation of the HFE intervention. Emmons and McCullough (2004) suggested that appreciation is a key component of human gratitude and can be actively generated and sustained. The authors believe that a successful system HFE project should be associated with clients who would show much appreciation to the HFE specialists. Consequently, understanding factors affecting the generation of such an appreciation is valuable and useful to the HFE professional.

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1.2. An overview and the six rated attribute scores

This study reviewed thirteen projects in which HFE principles were applied to change the systems of work. All projects were conducted in the industry and the systems of work were real. Further explanation of project selection can be found in Section 1.2. In 2012, Dul and his colleagues proposed that all system ergonomics has three characteristics: (i) it has a system approach, (ii) it is design driven, and (iii) it is outcome focused. Hence, this paper reviewed the 13 selected projects in the following five aspects: (i) the system(s) of work; (ii) the approach adopted to apply the HFE principles; (iii) the implementation plan; (iv) the outcomes; and (v) levels of appreciation. The first four aspects correspond to the three key characteristics proposed by Dul and his colleagues (Dul et al., 2012) and the last is this study's unique contribution as explained in Section 1.1.

In order to provide some levels of quantitative analyses, aspects (ii) to (v) were further evaluated by six project attributes. For each project, these six attributes were numerically rated by the author who conducted the projects, respectively. More details on how the ratings were done can be found in Section 1.3. These six attributes were: (a) did the client have an HFE specialist? (b) the level of clarity of HFE requirements as written in the contract; (c) the level of team organization to facilitate the application of HFE intervention; (d) the level of HFE awareness at senior and working level of the client's company; (e) how close are the HFE requirements to the key performance index (KPI) of the project; and (f) the level of appreciation received in response to the HFE intervention. The first four attributes were associated with the approach and the implementation of HFE principles and attribute (f) was the level of applause given to the HFE specialist by the clients. As there are 13 projects and six attributes, 78 ratings were given. How and why a particular rating had been assigned is explained in Sections 1.3 and 2.

Relationships among these key factors and levels of appreciation of HFE interventions were found to conform to the prediction rules as described in a Kano's model of quality. That model was introduced by Dr Noriaki Kano to explain and predict the relationships among product attributes and customers' satisfaction (Kano, 2001; Kano et al., 1984). More details about how this model can predict levels of appreciation of HFE intervention can be found in Section 3. A review of the literature reveals no previous application of Kano's analyses to factors associated with the appreciation of HFE interventions. Part of the material reported in this paper was verbally presented by the first author at the keynote speech of the First Human Factors and Ergonomics Society of Philippines Conference held in Manila.

1.3. How were the 13 projects selected and who rated the project attributes?

The 13 projects were selected and filtered from all the HFE related projects conducted by the two authors using the following filtering criteria: (i) all academic research projects were excluded as the focus of this paper was on industrial projects; (ii) projects focused on the development of a specific product was excluded when the scope of such projects was not board enough to study the impact of such a product on a system of work; and (iii) projects purely involved HFE training were excluded. Regarding the third exclusion criterion, the authors acknowledge that HFE training would eventually make an impact on the systems of work. However, this paper focuses on HFE interventions through participation with real workforce (Kogi, 2006). After applying the exclusion criteria, 7 and 6 projects conducted by the first and the second authors remained, respectively. All selection was done before the rating was conducted. In other words, the authors did not exclude any project because of their rated results.

The author who implemented the HFE intervention was the one who rated the project. The first author rated projects IT1, IT2, Console 1, Console 2, Stress 1, Hearing 1 and Fall 1 and the second author rated the rest of the 6 projects. Cross rating was not done because only the HFE specialist who implemented the HFE intervention would have enough knowledge to assign the ratings. The authors acknowledge that the ratings had been subjective. Consequently, essential details to support the ratings were documented in Section 2 and in Tables 2–6. In addition, credentials of the authors in the field of HFE can be founded in Authors contribution. Furthermore, sensitivity analyses of the findings to possible inter-rater variation were conducted (Section 3).

2. Essential project details to support the rated attributes

2.1. The scope and objectives of the review

The focus of the review was not on specific outcomes of individual projects. Rather, the objective was to identify common factors influencing the level of appreciation received after applying the HFE interventions. In some of the cases reviewed, HFE principles had been correctly implemented but the related outcomes generated little or no appreciation. A change in the levels of appreciation was observed throughout the course of the project, but this was not the focus of this study. For this study, the rated level of appreciation refers to the final appreciation given to the HFE specialist after the project has been completed.

2.2. An overview of the selected projects

The projects reviewed in this study covered a range of industries and organizations from trading firms to multi-national companies, and systems of work ranged from software databases to control consoles and quality assurance systems.

A total of thirteen HFE-related projects were reviewed. Four of them were related to the design and development of information technology systems (projects IT1 to IT4) and another four to the design and development of control consoles (Console 1 to Console 4). There were also projects related to stress (Stress 1), hearing (Hearing 1) and fall hazard (Fall 1). The remaining two projects had broad scopes and are best described as a risk management system (System 1) and a communication system (System 2). Key project attributes with rated levels are summarized in Table 1. The rated levels were assigned by the investigators (authors), who also directly implemented the HFE interventions.

2.3. Criteria used to rate the six attributes

Details of the six attributes (a to f) can be found in Section 1.2. The first attribute (attribute a) was whether the client had an HFE specialist. The answer was either 'yes' or 'no' and the criteria had been very straight forward. For the rest of the five attributes, the authors used a rating from 1 to 10 to represent the different levels of fulfillment. The anchoring points for the 10-point ratings used to represent attributes b, c, d, e and f are summarized in Tables 2–6, respectively. Most of the attributes were multi-dimensional and were represented by more than one descriptor. For example, in Table 2, contractual HFE requirement (attribute b) was represented by written commitment to (i) board HFE issues; (ii) HFE implementation; and (iii) HFE requirement. These descriptors were developed, clustered, and extracted from descriptions of the 13 projects.

Table 1
A summary of project attributes with rated levels of hypothetical factors that may associate with levels of appreciation of HFE intervention.

Attributes	Projects with HFE interventions												
Project code	IT1	IT2	IT3	IT4	Console 1	Console 2	Console 3	Console 4	Stress 1	Hearing 1	Fall 1	System 1	System 2
Business nature	Textile	Textile	Metal part manufacturer	Electric power	Emergency services	Public transport	Military	Public transport	Public transport	Logistics	Logistics	Military	Mining
Project Size (US$) and duration	700K (24 months)	100K (12 months)	Free (12 months)	30K (18 months)	800K (14 months)	10K (6 months)	>1 billion (15 months)	250K (6 months)	30K (5 months)	12K (2 months)	25K (12 months)	>1.5 billions (18 months)	50K (18 months)
Did the client have an HFE specialist?	No (0/10)	No (0/10)	No (0/10)	No but had safety specialist. (5/10)	No (0/10)	Yes (10/10)	Yes (10/10)	No (0/10)	No (0/10)	Yes (10/10)	No (0/10)	Yes (10/10)	No (0/10)
Clear HFE requirements in the contract[a]	10/10	8/10	7/10	2/10	7/10	10/10	10/10	7/10	10/10	10/10	10/10	10/10	3/10
Clear organization for applying HFE[a]	7/10	9/10	10/10	1/10	7/10	10/10	10/10	7/10	10/10	10/10	10/10	10/10	1/10
HFE awareness at senior & working Level[a]	8/10	10/10	9/10	1/10	7/10	10/10	7/10	6/10	7/10	10/10	5/10	7/10	2/10
How close are the HFE requirements to the key performance index (KPI) of the project[b]	1/10	10/10	10/10	2/10	5/10	10/10	8/10	8/10	10/10	10/10	10/10	8/10	2/10
Client's appreciation toward HFE intervention[a]	1/10	9/10	10/10	1/10	5/10	9/10	7/10	6/10	9/10	10/10	2/10	7/10	0.5/10
%Staff time (c.f. cost)	5%	10%	30%	2%	10%	100%	6%	17%	70%	100%	100%	6%	1.5%

[a] Subjectively rated by the investigators from 1 to 10; please refer Section 2 and Tables 2–5.
[b] Subjectively rated by the investigators from 1 to 10; 10 is complete overlap, see Table 6.

Table 2
Anchoring descriptions related to the level of clarity of HFE requirements in the contract (attribute b).

Scale level	Anchor description
10	Clear and specific written commitment to (i) board HFE issues; (ii) HFE implementation and (iii) HFE contractual requirements
8	Clear and specific written commitment to both (i) board HFE issues and (ii) HFE implementation, but (iii) no specific HFE contractual requirements
5	General and non-specific written commitment to both (i) board HFE issues and (ii) HFE implementation; but (iii) no specific HFE contractual requirements
3	General and non-specific written commitment to (i) board HFE issues; (ii) no specific commitment to HFE implementation and (iii) no specific HFE contractual requirements
1	No mention of (i) board HFE issue; no specific commitment to HFE implementation; and (iii) no specific HFE contractual requirements

Table 6 indicates that the assignment of a rating of '10' was associated with at least one "out-of-expectation" surprised achievement associated with the HFE intervention. Examples include: (i) the clients in project IT2, having lowered their expectations because of project IT1, were pleasantly surprised to find that their colleagues in the merchandizing department were delighted to see that they did not have to change their work practices in order to upgrade to the new digital sourcing system. (ii) The clients in project IT3, they were so impressed with the new system that they offer job openings to two members of the HFE project team. (iii) The client in project Stress 1 was delighted to see that the HFE intervention led to the discovery of the "culprit" junction that had caused much stress on their drivers and (iv) the clients in project Hearing 1 were excited to see that the observations by their train captains were scientifically validated. In the rest of Section 2, essential details of the 13 projects are summarized.

2.4. Essential background of the 13 projects

2.4.1. IT1: A global sourcing database for a consortium of textile manufacturers

The objective of the project was to develop a global sourcing database for small and medium sized garment and textile companies in Hong Kong. The deliverable of the project was a

Table 3
Anchoring descriptions related to the level of team organization to facilitate the application of HFE intervention (attribute c).

Scale level	Anchor description
10	The HFE specialist, who implemented the HFE intervention, was also the project manager (PM). There was at least one other staff officially assigned to assist the implementation. If the HFE specialist was not the PM, there should be an HFE specialist counterpart at the client's side.
8	The HFE specialist, who implemented the HFE intervention, was not the PM but had the direct support of the PM or was the deputy PM or co-PM. At least one other staff was officially assigned to assist the implementation.
5	The HFE specialist, who implemented the HFE intervention, was not the PM. The PM did not directly support the implementation but was in favor of the implementation. At least one other staff was officially assigned to assist the implementation.
3	The HFE specialist, who implemented the HFE intervention, was not the PM. The PM was neutral about the HFE implementation. There was no other staff assigned to assist the HFE implementation.
1	The HFE specialist, who implemented the HFE intervention, was not the PM. The PM was not in favor of the HFE implementation. There was no other staff assigned to assist the HFE implementation.

Table 4
Anchor descriptions related to the level of HFE awareness at senior and working levels at the client's company (attribute d).

Scale level	Anchor description
10	The HFE awareness at both senior and working levels at the client's company had been high. In other words, they knew and agreed on the benefits that HFE implementation can bring to their systems of work.
8	The HFE awareness at both senior and working levels at the client's company had been high but they had biased understanding that HFE implementation had to be expensive or their awareness was a leap of faith rather than based on complete understanding of the benefits of HFE.
5	The HFE awareness at senior and working levels at the client's company had been partial. In other words, either the awareness was high in one level and low in the other or was partial at both levels.
3	The HFE awareness at either senior or working levels at the client's company had been missing and the remaining awareness was only partial.
1	The HFE awareness at both senior and working levels at the client's company were low or non-exist. In other words, they neither understood nor agreed on the benefits that HFE implementation could bring to their systems of work.

centralized client-server database to provide overseas buyers easy access to companies with relevant capabilities. The system of work to be improved in the project was the database and its interactions with textile accessory suppliers, the garment and textile manufacturers and most importantly, overseas buyers. A higher level system of work related to this project was how this database was being integrated into the sales and marketing departments of various Hong Kong based textile companies. The project's key performance index (KPI) was the number of companies that would adopt and integrate this digital database platform into their respective business operations. The database used both the Internet and the telephone network to interconnect the stakeholders. The objective was to improve the efficiency of information exchange that could lead to new business opportunities.

The main challenge was the replacement of the physical samples with digital representations. For example, most button suppliers at that time used real physical samples to represent their products and to illustrate their companies' capabilities. There were no digital versions of those samples and just taking a picture, a series of pictures or even a video could not convey the tactile structure considered important for such products. At the end of the project, the issue of tactile feedback could not be completely resolved.

Table 5
Anchor descriptions related to how close are the HFE requirements to the key performance index (KPI) of the project (attribute e).

Scale level	Anchor description
10	The HFE intervention directly advanced all the KPIs of the project. In other words, the objectives of HFE interventions and the KPIs were completely overlapped.
8	The HFE intervention directly advanced about 80% of the KPIs of the project. In other words, the objectives of HFE interventions were a sub-set of the KPIs.
5	The HFE intervention directly advanced about 50% of the KPIs of the project. In other words, the objectives of HFE interventions were a sub-set of the KPIs.
3	The HFE intervention directly advanced about 30% of the KPIs of the project. In other words, the objectives of HFE interventions were a sub-set of the KPIs.
1	The HFE intervention directly advanced only 10% or less of the KPIs of the project. In other words, the objectives of HFE interventions were a sub-set of the KPIs.

Table 6
Anchor descriptions related to the level of appreciation received from the clients in response to the HFE intervention (attribute f).

Scale level	Anchor description
10	The clients expressed gratitude of appreciation directly to the HFE specialist for his or her contributions because the results of HFE intervention had been exciting and exceeded the expectations of the clients. In other words, the clients were impressed and they were able to highlight at least one out-of-expectation example of HFE intervention.
8	The clients expressed gratitude of appreciation directly to the HFE specialist for his or her contribution but there was a sense of more could be done. In other words, the clients were impressed and single out an out-of-expectation contribution by the specialist but also were expecting a bit more.
5	The clients expressed gratitude of satisfaction to the HFE specialist because they were satisfied that the specialist had made his or her fair contribution. However, the clients were neither impressed nor excited. When asked, clients could remember a lot of "helpful" activities associated with the HFE intervention but could not single out an out-of-expectation example.
3	The clients thought that the HFE specialist had been helpful but they did not think the HFE intervention had made much contribution toward the overall success of the project. When asked, clients could only say that HFE intervention was needed but could not remember what the intervention was.
1	The clients had overlooked the contribution of the HFE specialist and did not think that they made any contribution toward the overall success of the project. In other words, the clients did not think they need the HFE intervention. When asked, clients could not remember what the HFE intervention was.

In twenty-four months, the project team successfully developed and delivered a client-server based sourcing system and the funding body was satisfied with the deliverables. In particular, the menu interface was tested and shown to be user-friendly. Indeed, it was rated as excellent by sampled users during the evaluation period. However, the number of companies who chose to adopt it, a key performance index, was not as high as the steering committee had hoped. Also, survey results revealed that although the user-friendliness of the GUI was rated as excellent, it was not the main consideration in deciding whether or not to use the database.

Although the project was successfully delivered and the menu design was rated as excellent, the staff who designed the menu did not receive much appreciation for their application of HFE principles (see Table 1). Debriefing indicated two possible reasons for the lack of appreciation: (i) the stakeholders thought that a user-friendly GUI, though excellent in its performance, only satisfied the basic requirement of the system; and (ii) the focus of expectations had been shifted from a user-friendly GUI to the capturing of product capabilities through digital media. In particular, the failure to capture tactile information was considered as an imperfection of the final system.

2.4.2. IT2: A customized global sourcing database for a textile design and manufacturing firm

This was an extension of project IT1 and it was solely funded by a textile manufacturer who had participated in that earlier project. The company had received very positive feedback from their purchasing department about the use of the digital sourcing system during project IT1. Consequently, they hoped to develop a customized global sourcing database exclusive to their firm. The main system of work in the project was the sourcing database being used by firm's purchasing staff. The KPIs were: (i) the level of acceptance shown by the purchasing staff toward the new database system and (ii) a smooth transition of work practices as facilitated by HFE intervention.

With the experience accumulated in project IT1, the inability to digitize tactile information was expected and stated clearly in the proposal. Learning from the mistakes in project IT1, the HFE requirements were clearly listed in the contract, but the details were less specific to leave room for subsequent modification as the project progressed.

The HFE practitioner worked with the merchandising department and designed user-friendly workstations which allowed easy capturing of digital images of their existing product samples. The workstation involved much automated features such as an automated turntable and computer-controlled cameras.

In twelve months, the project team successfully developed and delivered an Internet-based sourcing system for the company. In addition to a user-friendly software menu, semi-automatic workstations with digital cameras were designed and tested. They were adjudged an acceptable and workable solution to aid workers in capturing digital product signatures. The project output was well received and the company was very satisfied with the deliverables. The users in the sourcing department were pleased to fully integrate the new system into their existing work practices. The contribution of HFE specialists to the smooth transition of work practices was much appreciated (9 out of 10, Table 1). There were still some complains about the lack of tactile information in the digital product representations, but it was understood that this was outside the scope of the HFE interventions.

2.4.3. IT3: A supply chain management system for a metal parts manufacturer

This project involved developing an Internet-based software system to manage stock levels, price estimations, invoice generation, production planning, as well as accounting for a metal parts manufacturer. The company was a typical family-run business in Hong Kong. It had a trading office in Hong Kong and a factory in the southern part of China. Before the project, bookkeeping had been on paper and communication among the customers, the trading office and the factory relied on face-to-face conversations, telephone conversations and facsimile messages. This had caused much miscommunication between the factory and the office, resulting in costly under- or over-estimations of production capacity. In addition, the family members who had been running the business were getting old and new employees were not able to use the traditional paper-based system effectively because it was heavily entangled with family activities. For example, much knowledge about order status was communicated to the trading office during weekend family gatherings. It was decided that an Internet-based enterprise resource planning (ERP) solution should be applied in order to modernize the company.

The systems of work in the project were the business processes managed and facilitated by the newly-developed ERP systems. The KPI was the smoothness of the transition in work practices. This was in fact a student project, so although the students did their best to specify the requirements in the project proposal, some details were missed and the level of clarity was rated as 7 out of 10 (Table 1).

After twelve months, a customized ERP system with multilingual interfaces were developed and implemented. Cultural issues in work flows were studied and accounted for in the new system. Feedback from all five users was very positive. In order to smooth out the transition of work practices, a fully integrated system of scanners, printers and digital cameras with an internet service provider and backup servers was designed, tested and delivered. The company was so impressed with the new system that they invited two team members to join the company. The HFE intervention was adjudged to be very well appreciated (10 out of 10, Table 1) as evidenced in part by the recruitment of the two students.

2.4.4. IT4: A risk management system for a power plant

The client was a 1000 MW power station in southern part of China with over 2000 staff plus an additional 500 to 1000 contractor workers often on the site depending on the need. The plant had been commissioned in the 1990s, and was considered relatively old by industry standards. Safety had always been addressed as part of operations management, but it was managed in a piecemeal and reactive manner, focusing on incidents and accidents after-the-fact. Headquarters was insisting on an improved safety management system which would be more proactive and systematic. The new safety management system was also required to implement risk-based management, an HFE program, and audits (both internal and external). The management of the power station would be accountable for achieving annual performance targets based on the ratings from the audits. The topic of HFE engineering was especially new to the power plant, and one of the project's tasks was to help establish such a program as part of the overall risk management system.

The systems of work involved in the project were the safety audit systems, and the KPIs were (i) the successful implementation of safety audits at the power plant and (ii) obtaining the resultant certification for the company. During the project, the HFE specialist did his best to explain the important contributions of HFE to safety, but the senior management did not pay much attention. The KPI of project IT4 was to successfully implement a safety risk management program. Unfortunately, the senior management of the power station was convinced that the KPI should be achieved by implementing the most basic and simple safety program with least amount pf effort. Consequently, the relevance of HFE to the KPI was rated as only 2 out of 10 (Table 1).

The work contract covered mostly safety management, paying inadequate attention to HFE. There were general commitments and requirements in the contract for safety management but with little or nothing specific to HFE. The clarity of the contractual requirement for HFE output was rated as 2 out of 10 (Table 1) and the company's senior management displayed almost no awareness of HFE (1 out of 10, Table 1).

After 18 months, although a basic risk management program was set up, its effectiveness was not adequately tested or evaluated. Some of the risk minimization measures were implemented, but not all. The clients demonstrated little interest in HFE. The link between HFE and safety was generally ignored. The staff's prime motivation was apparently to receive certification for the company as inexpensively as possible. Appreciation and interest among senior management was definitely weak or non-existent (1 out of 10, Table 1), while appreciation and interest among all other levels of staff were basic at best. In all cases, the expectations were weak.

2.4.5. Console 1: Re-design of workstation consoles and work flow for an emergency service

This objective of the project was to develop a tendering document to invite proposals to upgrade the city's emergency call handling services with the latest mobile digital technology so that it would be more robust against natural disasters and terrorist attacks. The KPIs were (i) the effective, efficient and secure dispatch of emergency services; (ii) seamless transitions between fixed-base and vehicle-based units so that callers would not notice whether they are calling to a fixed-base or vehicle-based centers; (iii) the existing operators' level of appreciation of the new system; and (iv) the robustness of the system.

The systems of work involved were the new emergency vehicle dispatch system and its interactions with its users. The task force consisted of a project team under the supervision of a steering committee. The steering committee had 28 representatives representing all the government stakeholders. They were all experts in

their respective domains, but none had any specialist knowledge of HFE although they had been very open-minded about HFE. The project manager in particular had high awareness of HFE issues as he was a former student of the one of two HFE specialists on the team. The level of awareness of HFE among the senior management of the client was rated as 7 out of 10 (Table 1).

Physiological and environmental stress factors were identified, and the design of the new console addressed them and minimized the level of rated stress. Examples include repetitive strains and lighting glares. The project was successfully completed in 14 months and a tendering document with HFE specifications was delivered.

Although HFE constituted only about 10% of the project, it helped to achieve half of the KPIs. Consequently, the project manager was very appreciative of the contribution of HFE. In fact, the project manager cited HFE considerations as a major contributing factor to the success of obtaining funding in the first place. The level of appreciation was rated as 5 out of 10 (Table 1), which might be considered quite high given that HFE was only 10% of the whole project.

2.4.6. Consoles 2: Re-design of workstation consoles and the work flow of a ticketing office

A transportation company was relocating one of their ticket offices and was using the occasion to redesign the ticket selling consoles from an HFE perspective. The systems of work involved in the project were the workstation consoles used by the ticketing personnel. The KPI was their level of user acceptance of the new workstations. There were clear HFE commitments and specific HFE requirements at the proposal stages, and the clarity of HFE requirement in the contract was rated as 10 out of 10 (Table 1).

The task force consisted of one company representative and the project team. The company representative was a safety and health officer who had received some training in HFE. Adopting a "master-apprentice" approach, team members assumed the apprentice role and followed an experienced ticketing officer to learn and uncover the hidden structure of the work of selling tickets (Beyer and Haltzbalt, 1997).

After 6 months, new workstation consoles were redesigned to allow users to sit with their backs straight and resting on a back rest, and be able to perform their duties with neutral arm and wrist postures. It was suggested that PC mice be replaced by keypads so that the ticketing officers could use different fingers to perform their tasks instead of flexing the same fingers repeatedly. Also, users could choose to lock the wrist and fingers in a rigid posture and move the whole forearm to operate the keypads so as to avoid frequent flexing of wrists.

The newly console designs were welcomed and adopted as the prototypes for future ticket offices. However, the replacement of PC mice with keypads could not be implemented easily as it involved redesigning the ticket selling software. A compromise solution using touch screens was finally adopted. The HFE intervention was well received and appreciated (9 out of 10, Table 1). The one missing mark was related to the unwillingness to replace the PC mice with keypads, though the use of touch screens was a reasonable compromise solution.

2.4.7. Console 3: design and develop an integrated mission system for a military helicopter

This project involved designing and developing an integrated mission system for a multi-function military helicopter. The new helicopter had been designed and was being built by firms in two different countries, and the helicopter was intended eventually to be purchased by a number of countries worldwide. This project involved designing and developing a mission system for conducting anti-submarine, anti-ship and search-and-rescue missions. Life-cycle engineering was required.

The system of work dealt with the mission system itself (including its consoles) and its interactions with the operators. The KPI was the acceptance of the system by its users as an effective and user-friendly system for accomplishing the defined missions. HFE requirements were only part of the KPIs, which also included hardware and software functionality and overall system performance. Achieving all these requirements demanded a balanced approach, but in most cases HFE requirements were considered the highest priority. The closeness between the KPIs and HFE intervention was rated as 8 out 10 (Table 1).

The senior military management was very much aware of HFE because of their strong traditional interest in HFE. However, their concerns about cost and schedule were sometimes in conflict with HFE considerations. The level of awareness of HFE was rated as 7 out of 10 (Table 1).

After 15 months, the contract requirements with respect to HFE had been satisfied. The new mission system was well received and found to be generally effective by the clients in the field. The users and maintainers of the new helicopter showed much appreciation to the authors for the HFE interventions, even though the project managers were more concerned with the costs and schedules (7 out of 10, Table 1).

2.4.8. Console 4: design of an operations control center for a public transportation operator

This project involved designing an operations control center (OCC) for a public transportation operator with a daily ridership of over 2.5 million passengers. The OCC was to control the operations of several lines with many stations. The central controllers were to monitor the entire operation using a large screen display complemented by displays at several local desk-top workstations. This project addressed the design of the workstations, the consoles, other hardware, the human–machine interface (HMI) and environmental factors.

The system of work comprised the control center, the operators and their interactions. The KPIs were (i) the perceived user friendliness of the interfaces; (ii) the efficiency of operations; and (iii) the cost. Among the three KPIs, the first was considered the most important. There were general commitments and requirements dealing with HFE in the contract, especially regarding the consoles, controls and displays, but they were not specific. The level of clarity of HFE requirement as laid out in the contract was rated as 7 out 10 (Table 1). The closeness between the KPIs and the HFE intervention was rated as 8 out of 10 (Table 1) as the intervention was aligned with the main KPI.

After 6 months, the OCC design was delivered and was well received by the client. However, certain aspects were not as satisfactory. It was felt that other factors such as maintainability and cost had not been adequately considered. Consequently, the operators (users) of the client were moderately appreciative (6 out of 10, Table 1).

2.4.9. Stress 1: A study of work-related stress and workforce morale

A transportation company was concerned about low morale among its drivers. The management suspected the root cause might be associated with a series of accidents involving its vehicles. The authors were asked to investigate the problems, identify the root causes, and propose solutions. There was a clear commitment and specific requirement in the contract for HFE intervention (10 out of 10, Table 1).

The systems of work involved were driver–vehicle interactions. The KPI was the completeness of the factors identified to have influenced the stress and morale of the drivers. The HFE intervention thus aligned exactly with the KPI (10 out of 10, Table 1).

Heart rates of drivers at work were measured in real time as indicators of levels of stress. Road situations were also recorded in real time using several video cameras. The videos were used to encode levels of hypothetical factors, which were then correlated with the heart rate time series data. Pattern of heart rate variations were found to be related to repeated work procedures, and the sharp rise in heart rate was related to crossing a particular junction. The levels of stress indicated by measured heart rates were significantly associated with particular work procedures. Follow-up investigations successfully determined the root causes, and subsequent changes successfully relieved some of the drivers' stress. The company was very pleased with the outcome. This was evidenced by the immediate implementation by the company of the suggested changes. The HFE intervention was well received and appreciated.

2.4.10. Hearing 1: Re-examination of hearing among an aging workforce

This project came about when a company conducted a routine check of hearing among its aging workforce and some staff members failed, even though they were still able to hear audio warning signals as required by their job descriptions. This conflicting result led to the company inviting an HFE team to conduct tests to resolve the discrepancy. The objective was to scientifically verify whether or not workers who failed the hearing tests had significantly less ability to hear the warning signals than their colleagues who had passed.

The system of work was the workers performing their daily tasks in the presence of noise and audio warning signals. The KPI was the extent to which the recommended measures could resolve the conflict between the company's audiometric testing standards and the workers' measured ability to hear warning signals. Clear and detailed HFE requirements were written in the contract (10 out of 10, Table 1) and the KPI was completely aligned with the HFE intervention (10 out of 10, Table 1). Using field recorded noise and audio signals, an auditory vigilance test was designed and administered to test the workers' ability to correctly detect the presence or absence of the warning signal in the presence of noise. The results of the vigilance test confirmed that those workers who had failed the hearing test were nevertheless able to perform in the audio signal test with results similar to those of their colleagues with normal hearing. Spectral analyses provided physical evidence to support the perception findings. Solutions to improve the audiometric testing procedure were proposed.

The HFE intervention was well received and appreciated (10 out of 10, Table 1). Both the company's managers and the workers were please to see that their observations were scientifically validated.

2.4.11. Fall 1: fall hazard analyses for working on top of cargo containers

The objectives of Fall1 project were (i) to determine the root causes of fall hazards relevant to workers handing cargo containers and (ii) to develop measures to reduce fall accidents. The project was motivated by the increasing numbers of fatal falls among cargo handlers at a Chinese sea port. The system of work in the project was cargo handlers shifting containers at a cargo terminal, and the KPIs were: (i) the exhaustiveness of the set of root causes identified for falls among cargo handlers; and (ii) the effectiveness of the proposed solutions in reducing fall hazard.

Focus group interviews were conducted among supervisors to identify potential root causes of fall hazards. Their suggestions were then used to design a questionnaire which was administered to determine the most influential factors and work practices associated with fall accidents.

Fault tree analyses were conducted to investigate the root causes associated with past fall accidents. Six-sigma methodology was applied to facilitate the determination of the root causes so that measures were determined to reduce the rate of fall accidents. However, for liability reasons, the owners of the cargo terminals refused to allow the project team to implement its solutions and conduct trials. They verbally told the project team that their main concern was that if the solutions were successfully implemented, the workers might sue them for not implementing them earlier. In the end, only one of the two KPIs was fulfilled. At the time of the project the cargo handlers were all self-employed and the relationship between the owner of the terminals and the cargo handlers was a type of fee-for-service relationship. While the owner was willing to make some simple corrections to reduce fall hazard, he was afraid that once concrete evidence was collected through testing he would have to upgrade a lot of equipment at substantial cost. On the other hand, the self-employed cargo handlers were also afraid of higher rental fee for the equipment.

The HFE intervention was much appreciated by both the funding body and the Cargo Workers' Association, but not appreciated by the owners of the cargo terminals. The level of appreciation was evidenced by the invitation from the Association to show case this study in their annual dinner. Because of the refusal by the terminal owner to conduct the testing and evaluation, the overall level of appreciation was rated as 2 out of 10 (Table 1).

2.4.12. System 1: designing a telecommunications system for an air, land and sea military force

This project involved designing and developing a customized telecommunications system for the military. The telecommunications system included airborne, ship borne, land-based and soldier-carried equipment (including modern combat net radios, telephones, pouches and harnesses). A systematic engineering process had been applied covering the entire life-cycle of such a system. Safety and HFE were built into this process to ensure the system's performance requirements were met. There were clear and specific commitments and requirements for HFE interventions in the contract (10 out of 10, Table 1), but the efficiency and effectiveness of the telecommunications system were considered paramount.

The systems of work in this project were the telecommunication hardware and software and their interactions with the users. The KPIs were meeting the explicit requirements stated in the contract and providing a safe, reliable, user-friendly and effective telecommunication system in the field. Besides HFE requirements, the contract specified many other functional requirements, but in most cases user friendliness was considered as the highest priority. The closeness between the KPIs and HFE intervention was rated as 8 out of 10 (Table 1).

The senior officers were aware of the importance of HFE because the military has a strong traditional interest in HFE although they were also concerned with the budget.

HFE interventions were in phase with the system design and development. HFE considerations were applied in all aspects of the system's design, including the design of the hardware; the HMI; the controls, displays and alerts; the system's interactions with the environment and crew; and in the tests and evaluations. At the end of the project the contract requirements with respect to HFE had been satisfied and the new telecommunications system was well received and found to be generally effective by the officers and in the field.

The soldiers seemed deeply appreciative of the care taken with the system's HFE (7 out of 10, Table 1), even though the senior officers were more concerned about costs and schedules. Despite the general support for HFE considerations, limited resources sometimes compelled compromises.

2.4.13. System 2: A risk management system for 8 coal mines

The client was a large coal mine operator in China with 8 mines that were mostly underground and annual production of more than

10^8 metric tons. Each mine had over 200 staff with an additional 200 to 600 contractor workers depending on the need at the time. The mining operation was highly mechanized applying longwall mining technology (United States Department of Energy, 1995), so relatively few staff was actually required underground. Each mine's entire mining operation was basically controlled and monitored from an above-ground control center. The operation was among the most modern and productive mining operation in the country at that time. Safety had always been addressed as part of operations, but it was managed piece-meal and reactively, focusing on incidents after-the-fact. A need for a more proactive and systematic system was, however, perceived. Risk-based management, an HFE program and internal and external audits were considered necessary. The mine managers were to be given performance targets in terms of the audit findings and held accountable for achieving them. The topic of HFE was especially new to the company, and one of the tasks under this contract was to establish such a program as part of the overall risk management system. There were general commitments and requirements in the contract for safety management, but those related to HFE were unclear. Their clarity was rated as 3 out of 10 (Table 1). The level of awareness of HFE among the senior management was also poor (2 out of 10, Table 1).

The system of work in this project was the mining operation and the use of a risk management audit system to detect safety issues in the mines. The KPI was the extent to which the safety management system was successfully implemented. HFE had little part to play in that success, so the KPI and was not well aligned with HFE intervention (2 out of 10, Table 1).

The task force consisted of client representatives plus the project team. The client had a safety manager but he did not receive any training in HFE, while the project team included an HFE specialist. The project manager was not an HFE specialist and was not directly involved in the HFE intervention. Perhaps as a result, the project covered mostly safety management and inadequate attention was devoted to HFE.

The basic ergonomic risks survey was completed and the risks identified were prioritized for remedial action, the action was piece-meal rather than systematic. Implementation, tests and evaluations of effectiveness were not adequately followed up. Nonetheless, the project was successful in terms of its KPI. The safety management system was successfully implemented and the mine operator was pleased to have fulfilled the company's requirements that an audit system was in placed.

Appreciation and interest among senior management was definitely weak or non-existent (0.5 out of 10, Table 1), while appreciation and interest among other levels of staff were basic. In all cases the expectations were weak.

3. Factors associated with levels of appreciation of HFE interventions: an analysis

Some factors which might, hypothetically, affect the appreciation of an HFE intervention are listed and rated in Table 1. The ratings were assigned by the HFE specialists (also the authors) who applied the interventions and were the ones who received the appreciation. Evidence supporting the numerical ratings has been discussed in Section 2. The hypothetical factors are (i) whether the client had HFE specialists on staff; (ii) clarity in stating HFE requirement in the project contract; (iii) an organization structure facilitating the application of HFE principles; (iv) awareness of HFE among the client's senior management; and (vi) alignment between HFE intervention and the project's key performance indices. Spearman correlation tests were conducted to test the relationships among these factors and the levels of appreciation received by the project teams. Spearman correlation was used as it is more robust against the use of data whose distribution deviates from normality. Results of the correlations are shown in Table 7.

In four of the thirteen projects, efforts to apply HFE were poorly received and not appreciated by the clients. Those four projects were IT1, IT4, Fall 1 and System 2, and their rated levels of appreciation are 1, 1, 2, and 0.5 out of 10, respectively (Table 1). In project IT1, the system of work was a new Internet-based sourcing system and the KPI was the number of textile companies that would adopt the new system and use it in their sourcing. At the proposal stage, the requirement for HFE was actually clearly laid out and written into the contract. However, the project team had underestimated the scope of the HFE intervention required. They were hoping that solving the usability issues would be enough to encourage use of the new system. As the project progressed, however, it became clear that there was a fundamental short-coming in the digitizing

Table 7
Results of Spearman's correlation tests conducted on rated level of project attributes as shown in Table 1 (* for correlations with $p < 0.05$ and ** for correlations with $p < 0.01$).

Attributes	Size (US$)	Duration	Client has HFE specialist(s)	HFE requirement in contract	Organization structure for applying HFE principles	Awareness of HFE at senior level	Alignment between KPI and HFE intervention	Appreciation received for HFE intervention
Size (US$)	$\alpha = 1.0$ ($p = 0.000$)	$\alpha = 0.557^*$ ($p = 0.048$)	$\alpha = 0.046$ ($p = 0.881$)	$\alpha = -0.057$ ($p = 0.853$)	$\alpha = -0.273$ ($p = 0.367$)	$\alpha = -0.276$ ($p = 0.362$)	$\alpha = -0.589^*$ ($p = 0.034$)	$\alpha = -0.410$ ($p = 0.164$)
Duration		$\alpha = 1.0$ ($p = 0.000$)	$\alpha = -0.042$ ($p = 0.892$)	$\alpha = -0.363$ ($p = 0.388$)	$\alpha = -0.518$ ($p = 0.070$)	$\alpha = -0.472$ ($p = 0.103$)	$\alpha = -0.818^{**}$ ($p = 0.001$)	$\alpha = -0.722^{**}$ ($p = 0.005$)
Client has HFE specialist(s)			$\alpha = 1.0$ ($p = 0.000$)	$\alpha = 0.398$ ($p = 0.178$)	$\alpha = 0.414$ ($p = 0.159$)	$\alpha = 0.240$ ($p = 0.430$)	$\alpha = 0.100$ ($p = 0.746$)	$\alpha = 0.298$ ($p = 0.323$)
HFE requirement in contract				$\alpha = 1.0$ ($p = 0.000$)	$\alpha = 0.762^{**}$ ($p = 0.003$)	$\alpha = 0.421$ ($p = 0.152$)	$\alpha = 0.417$ ($p = 0.156$)	$\alpha = 0.373$ ($p = 0.209$)
Organization structure for applying HFE principles					$\alpha = 1.0$ ($p = 0.000$)	$\alpha = 0.588^*$ ($p = 0.035$)	$\alpha = 0.782^{**}$ ($p = 0.002$)	$\alpha = 0.743^{**}$ ($p = 0.004$)
Awareness of HFE at senior level						$\alpha = 1.0$ ($p = 0.000$)	$\alpha = 0.536$ ($p = 0.059$)	$\alpha = 0.769^{**}$ ($p = 0.002$)
Alignment between KPI and HFE intervention							$\alpha = 1.0$ ($p = 0.000$)	$\alpha = 0.822^{**}$ ($p = 0.001$)
Client's appreciation toward HFE intervention								$\alpha = 1.0$ ($p = 0.000$)

technology and important tactile information associated with textile accessories could not easily be digitized. This quickly became the main barrier that deterred the textile companies from adopting the new system. It was also true that in project IT1, implementing a user-friendly interface did not contribute much toward achieving the KPI. The users simply considered a user-friendly interface to be a very basic requirement. According to Kano's model of quality (Kano et al., 1984; Kano, 2001), once a product attribute has existed for a long time, it is likely be perceived as a basic and "must-be" feature. Its presence can no longer excite the users, but its absence can lead to great disappointment. In project IT1, user-friendliness was taken for granted, and therefore failed to excite the users and encourage them to adopt the new Internet-based sourcing system.

A review of Sections 2 and Tables 1–6 shows that projects IT4 and System 2 had many attributes in common. In project IT4, the system of work was a new safety and risk management auditing system in a power plant. The KPIs were (i) the successful implementation of the audit system and (ii) certification for the mother company. In project System 2, the system of work was a safety management system for 8 mines and the KPI was the level of implementation of that system. Both projects were characterized by: (i) unclear and non-specific HFE requirements in the contract; (ii) lack of awareness of HFE among the senior management of the client; (iii) no sound organization structure for applying any HFE initiatives, and (iv) the HFE intervention was not aligned with the KPI. Another common characteristic was that both projects were driven not by internal needs, but were initiated externally from company headquarters. Further studies are required to study the influence of such factors.

Still, both projects IT4 and System 2 were successful in terms of their respective deliverables and the achievement of their KPIs. Indeed, both the power plant operator and the mine operator were pleased to have implemented the safety audit system and successfully satisfied the certification requirement. As HFE practitioners, we have to acknowledge that we frequently participate in similar projects where HFE clearly is not the main theme. Following the logic of Kano's model, at least the HFE approach was not considered as old, basic and a "must-be" factor in projects IT4 and System 2, because the management had little awareness of HFE (1 or 2 out of 10, Table 1). Taking this one step further would mean that there may be an opportunity to turn HFE interventions into some sort of new and exciting event that would capture the interests of the clients.

Table 7 indicates that appreciation of HFE interventions is significantly and positively correlated with shorter project duration ($p < 0.01$); better organization for applying HFE principles ($p < 0.01$); awareness of HFE at senior level ($p < 0.01$) and alignment between the KPIs and HFE intervention ($p < 0.05$). According to Kano's model of quality (Fig. 1), these factors can be considered as performance predicting factors that are positively associated with user satisfaction. The correlation between project duration and appreciation might be explained by the very significant negative correlation between the KPI alignment and project duration ($p < 0.001$). The benefits of aligning the objectives of the HFE intervention with the KPIs are consistent with the concept of participatory ergonomics in which HFE interventions are expected to increase the overall productivity of an enterprises (Kogi, 2006).

As stated in Section 1.3, 7 out of the 13 projects were rated by the first author and the rest of the projects were rated by the second author. In order to test for any inter-rater inconsistency in the rated appreciation levels, the rated levels of appreciation were ranked among those rated by the same rater. These ranks (1–7 for data from the first author) and (1–6 for data from the second author) were then mapped to a rating scale of 1–10. If two projects had equal ranks, e.g., 4th and 5th, they were assigned the averaged tank

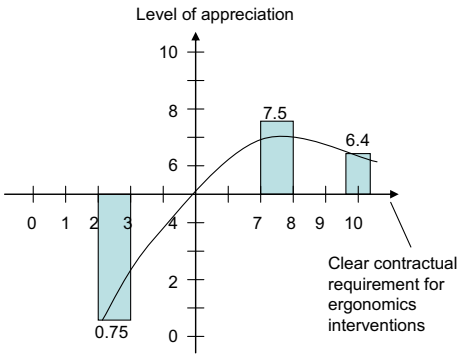

Fig. 1. The relationship between "clear contractual requirement for HFE intervention" and "levels of appreciation received for applying HFE principles" among the 13 projects. It is a scatter plot between the mean rated levels of appreciation for HFE intervention against mean rated levels of clarity of contractual requirement. When the levels of contractual clarity were at 2 or 3, the levels of appreciation were at 0.5 and 1 (hence, mean of 0.75). When the levels of contractual clarity were at 7 or 8, the levels of appreciation were at 9, 10, 5 and 6 (hence, mean of 7.5). When the levels of contractual clarity were at 10, the levels of appreciation were at 1, 9, 7, 9, 10 and 2 (hence, mean of 6.4).

(i.e., 4.5). Using these "normalized" rated appreciation level. Spearman correlation tests, whose results are shown in Table 7, were repeated. Results indicated that patterns of significant correlation results were similar. In particular, the levels of "normalized" appreciation of HFE interventions was also significantly and positively correlated with better organization for applying HFE principles ($p < 0.01$); awareness of HFE at senior level ($p < 0.01$) and alignment between the KPIs and HFE intervention ($p < 0.05$).

It is not surprising that better organization and better awareness of HFE might raise the level of appreciation for the application of HFE principles. However, the absence of any significant correlation with having HFE specialists on the client side and with clearer contractual requirements for an HFE approach seems surprising. The presence of an HFE specialist on the client's side follows the pattern of an exciting and "attractive" factor in Kano's model: the absence of a specialist did not strongly affect appreciation (a mean of 5.3 instead of zero), but the presence of such a specialist was associated with very high levels of appreciation (a mean of 8.3). When projects rated by the same authors were clustered and analyzed separately, similar patterns were obtained. For the 7 projects rated by the first author, the absence of HFE specialist on the client's side gave a mean rated appreciation of 5.2 instead of zero but the presence of such a specialist gave a rated level of appreciation of 9.5. For the 6 projects rated by the second author, the absence of HFE specialist gave a mean rated appreciation of 4.4 and the presence of the specialists gave a rated appreciation level of 7.

Clear contractual requirements, by contrast, fit the pattern of an old, basic and "must-be" factor according to the Kano's model. Fig. 2 illustrates the relationship between the level of appreciation and the clarity of the contractual requirements. It shows that the presence of clear contractual requirements did not predict significantly more appreciation, but their absence was associated with large reduction in appreciation (Fig. 1). Again, when data rated by the same authors were analyzed separately and plotted together on the same graph, the curves followed similar trend of a "must-be" factor: the absence of contractual requirements gave 0.75 rated appreciation and the presence of contractual requirement gave rated appreciation data ranging from 6 to 8.

Dul et al. (2012) proposed that cost-and-benefit analyses of HFE intervention would help to educate system decision makers about the importance of HFE. Unfortunately, exact figures about the cost and returns of HFE intervention in these 13 projects were not

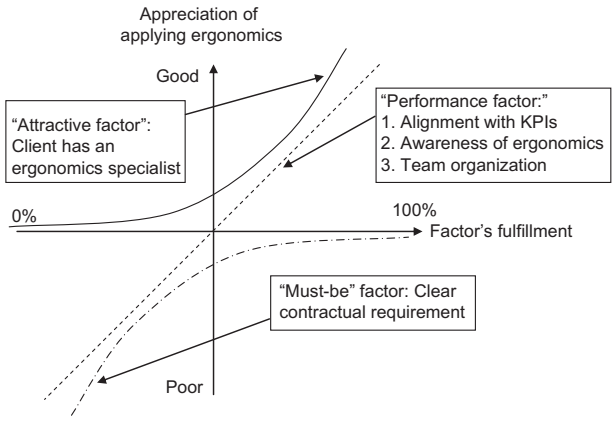

Fig. 2. The "attractive", "performance related", and "must-be" factors and their associations with levels of appreciation of HFE interventions. The 3 types of factors are defined according to Kano's model of quality (Kano et al., 1984).

completely known. The closest to the cost of intervention were in terms of manpower dedicated to the HFE intervention and they were summarized in the last row of Table 1. The amount of man-power directly involved in implementing the HFE intervention was quantitatively estimated so that a percentage of that over the total man-power could be calculated. For example, in project IT1, the project team had 6 full-time staff and 5 part-time staff. One full-time staff dedicated about 40% of her time on the project and the ratio of the man-power directly involved in implementing the HFE intervention was $0.4/(6 + 2.5) = 0.047$ (about 5%). Similarly, it is difficult to evaluate the 'benefits' of HFE intervention. In this study, the closest measures were the levels of appreciation toward the HFE contribution rated by the authors (second last row, Table 1). Not surprisingly, as the % of man-power directly involved in HFE implementation increased, the level of client's appreciation toward the HFE intervention also increased and they were significantly correlated ($p < 0.02$, $\alpha = 0.67$, Spearman correlation). The exception was project Fall 1.

In project Fall 1, the system was the interactions among cargo handlers, the cranes and the cargo containers. The KPIs were (i) the exhaustiveness of the root causes of falls identified and (ii) the effectiveness of the proposed solutions in reducing falls. The eventual poor appreciation of the HFE intervention was due primarily to a change in the attitude of the cargo terminal owner. When emerging evidence indicated room for improvement, the owner realized that further HFE intervention could be a threat. Fall 1 was funded by a quasi-governmental agency and it turned out that the KPI and the interests of the cargo terminal owner diverged. Further studies are needed to investigate to what extent such divergence affects the appreciation of HFE interventions.

4. Proposed steps to promote the appreciation of HFE interventions

To err is human, but HFE practitioners should be the first to learn from their mistakes. What can be learnt from the four projects that failed to attract much appreciation for their HFE interventions?

In projects IT4 and System 2, all three "performance predicting" factors were assigned as low. The clients had a poor awareness of HFE, the team lacked good organization, and the projects' KPIs were not well aligned with the benefits HFE can provide. To change all three would involve changes which are more fundamental. This finding echoes with the importance formulating HFE values among dominant stakeholders as suggested by Dul et al. (2012). In both projects the need for a safety audit system was imposed from their respective headquarters, and it would be fair to say that they were "pushed" into the projects. It is not surprising that the senior managers, who had little awareness of HFE, were not interested in HFE intervention. This indicates that the 'system decision makers' (Dul et al., 2012) in projects IT4 and System 2 were not educated about the values of HFE. But as has been explained, lack of awareness could actually present an opportunity to introduce the HFE perspective as something new, useful and attractive.

Since alignment with a project's KPIs strongly predicts performance, practitioners should emphasize interventions which directly address the KPIs. In these two cases that might have meant getting further approval or better-quality certification. In other words, rather than teaching the client's senior management to appreciate HFE, practitioners should try to increase the scope of the certification scheme to cover HFE implementation. Such tactics could strengthen the power of the three performance predicting factors.

A review of project IT1 suggests that it was a mistake to assume that a more user-friendly interface would be enough to achieve the project's KPI of attracting users. This mistake could have resulted from a type of professional bias among the project team members (Reason, 1990). To minimize such mistakes, HFE practitioners must have a thorough understanding of the systems of work they study. They might, for example, learn and apply the "contextual inquiry" technique suggested by Beyer and Holtzblatt (1997) to ensure a deeper understanding of the system. This technique was in fact applied in projects Console 2 and Hearing 1 to align the HFE interventions with the projects' KPIs. The wrong assumption that a more user-friendly interface was all that was required echoes with the problem that the perceived value of HFE are often not accurate (Helander, 1999; Neumann and Dul, 2010).

In project Fall 1 the client suddenly became aware of a potential liability issue and refused to collaborate further. There is perhaps no simple, general solution to such a problem. It is interesting to note, however, that as in projects IT4 and System 2, the clients did not initiate the project. In this case, the project was initiated by the cargo workers' association and supported by a quasi-government agency. Further studies on how to carry out such HFE projects would be desirable.

5. Conclusions

Thirteen system HFE projects, conducted by the authors, have been reviewed. Three factors significantly and positively correlated with the levels of appreciation received are identified: (i) better organization for applying HFE principles ($p \leq 0.01$); (ii) awareness of HFE among senior client personnel ($p \leq 0.01$) and (iii) the relevance of HFE to the project's key performance index ($p \leq 0.05$). In Kano's model, these three factors would belong to the "performance predicting" category. These factors echoes the importance of HFE values among system decision makers as reported in Dul et al. (2012) as well as the biased perceived value of HFE among system stakeholders (Helander, 1999; Neumann and Dul, 2010).

Surprisingly, having an HFE specialist on the client's side and clear contractual requirements for HFE intervention did not correlate with the levels of appreciation. However, the relationships between these two factors and appreciation could be explained by Kano's model (Kano et al., 1984; Kano, 2001). Having an HFE specialist on the client's side follows the pattern of a new, exciting and "attractive" factor whose presence may greatly increase appreciation but whose absence has little effect. On the other hand, a clear contractual requirement for HFE intervention behaves like an old, basic and "must-be" factor in terms of Kano's model. Its presence is unremarkable, but its absence greatly reduces the level of appreciation. It should be noted that although

having an HFE specialist on the client's side and clear contractual requirements for HFE have not demonstrated a positive correlation with appreciation, those factors may still affect project outcomes by providing additional HFE know-how and support. The relationships between the types of factors and the level of appreciation of HFE intervention are summarized in Fig. 2.

In two of the four projects with poor appreciation of HFE, the awareness of HFE was very low. The lack of awareness of HFE suggested that the clients were new to HFE methodology. This presents an opportunity for practitioners to teach and cast HFE interventions as something that is new, exciting and "attractive". If that can be done, efforts to applying HFE principles to the systems of work will receive higher levels of appreciation.

Authors contribution

The credential of the authors was important because the authors were the ones who rated the 78 project attributes as shown in Table 1.

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