HYPERMEDIA:

AN APPLICATION OF BSE SYSTEMS UNDER A COLLABORATIVE DESIGN ENVIRONMENT

LEE YAN CHUEN

A thesis submitted to the Hong Kong Polytechnic University in accordance with the regulations for the degree of Doctor of Philosophy.

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Abstract

Refurbishment of a shopping centre is thought to be one of the most challenging projects for a building services engineer (BSE). Many projects are unique nature, and client requirements frequently change in an unpredictable manner. The tracking of original design intent, which is essential for decision-making when reviewing design change, is frequently a frustrating task. The design activities of a typical shopping centre improvement project undertaken by a multi-disciplinary project team of the Hong Kong Housing Authority are investigated. Research experience in different areas that address the issue of complex problem solving, as well as collaborative design, is also referenced and scrutinized. A literature survey in the hypermedia field indicates that hypermedia is an appropriate environment for collaborative tasks. By bringing together these research results and previous studies in the application of hypermedia for preliminary building services engineering design, a conceptual model of a four-level architecture that represents the collaborative design activities for developing a client's brief of a shopping centre refurbishment project is proposed. The challenges and opportunities of the hypermedia paradigm such as the author-reader relationship and the compatibility between information type and information container, which gives rise to the identification of key functions necessary for realization of the conceptual model into a prototype model, the Collaborative Design Hypermedia Model (CDHM), are explored. Various types of hypermedia authoring tools have been considered and HyperCard using Macintosh OS is chosen for the implementation. The CDHM prototype is evaluated using real project information. Project team members who participated in similar practice design work reviewed the model. The concepts and arguments that support the construction of CDHM have also been presented in three different International conferences as well as one construction IT journal. The majority of the feedback is supportive and positive. In conclusion, hypermedia is a pragmatic option that points to a direction for developing collaborative design tools in building services engineering applications.

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CHAPTER ONE

Chapter 1: Introduction

1.1 Background

This thesis documents the development of a computer-aided tool that is intended to assist a building services engineer collaborate with his project team counterparts in other construction disciplines, in the process of formulating a client's brief for a construction project. Anecdotal evidence suggests that an unpredicted request for design change could result in higher project costs. It has been reported that the tendency to squeeze the design team's fees reduces the level and quality of the resources allocated to the project, which gives rise to incomplete tender designs. The result is often a delay in the project with a subsequent claim for loss and damage [Carter, M., 1999]. Financial loss may be reduced if the amount of unpredicted design changes can be minimized. The cause of any unpredicted design change is at least twofold. First, there is a genuine need from the client. For example, shopping centre design changes resulting in a much larger cooling load to be provided by the landlord. Second, where an incorrect design option is used (probably by mistake) resulting in a design change to rectify the inconsistency. The first case is normally beyond control under normal circumstances. Any attempt to predict changes is bound to be fruitless when considering the uncertainties that may arise in meeting the client's aspiration as well as social norms. While prediction is unlikely to yield any useful solution to the problem, the next alternative is to keep the probability of misinformation as low as possible and to shorten the turn-around time for any design change. In order to investigate the nature of the problem and to explore the feasibility of the various alternative approaches to improve the situation, refurbishment of a shopping centre has been chosen by virtue of its complexity as a typical case study.

Design changes warrant subsequent revision to a client's brief to reflect the major design requirements. Therefore, the research project begins with the analysis of the design activities of a typical shopping centre refurbishment project undertaken by a multi-disciplinary project team of the Hong Kong Housing Authority. The Hong Kong Housing Authority (HKHA) is one of the largest developers in Hong Kong in terms of the commercial portfolio, i.e. over 932,000 m^2 in over 110 shopping centres [Hong Kong Housing Authority, 2000]. The HA Report also reveals that this commercial portfolio generates an annual rental income of over $4.7 billion with approximately $400 million spent for improvement to these shopping centres each year. Hence it can be seen that 1% saving in the improvement project cost implies a gain of $4 million. Clearly there is a definite financial advantage in looking for possible means to help shorten the turn-around time for processing design changes and to minimize any unnecessary abortive work or rework.

Recently, collaborative design has been suggested as a suitable approach to reduce the complexity of design problems. "*The need for collaborative decision-making in construction is amply demonstrated by the proliferation of research projects in concurrent engineering that are dedicated to such project as product data exchange, integration of product and process models, and workflow management.*" [Ugwu, et al 2000]. Clearly the authoring of a design brief is a group activity. Conventional design software seldom expects a multi-user scenario in a simultaneous manner. Web-based commercial packages that claim to facilitate collaborative working (such as Cimage) [Cimage NovaSoft, 2000] are essentially document management systems. (The term "collaborative" may have different meanings as far as implementation details are concerned.) Nevertheless, the collaborative working environment has to be dealt with if the real world situation is to be considered.

1.2 Research objectives

There are four main research objectives. First, the design procedures of a shopping centre refurbishment project are thoroughly investigated with a view to identifying critical activities and information types as far as the role of a building services engineer in a collaborative working environment is concerned. Second, the characteristics of hypermedia, including its strengths and weaknesses, are analyzed with regard to its suitability in representing the information identified in the first objective. Third, based on the results of the first two objectives, a conceptual collaborative design model will be constructed. Finally, a prototype model has to be built and evaluated against the main theme and argument, i.e. the feasibility of processing collaborative design in a hypermedia environment.

1.3 Methodology and scope of research

It has been suggested that increasing recognition of the value and appropriateness of qualitative studies (vs. quantitative studies) has emerged with regard to research in disciplines which lie between the natural science and social science, notably management of technology and engineering [Fellows & Liu, 1997]. Fellows/Liu further point out that one of the most commonly adopted approaches to the analysis of qualitative data is grounded-theory that seeks to develop theory out of the data collected during the study. They consider that a hypothesis is inappropriate for a qualitative study which seeks to carry out a fundamental investigation to identify what is occurring such as observing behaviour in a highly novel environment.

Pursuant to the above argument, a qualitative approach is adopted for this research project. The behaviour of the project team members is observed in respect of how they exchange design information. The management or the application of the hypermedia technology also comes under this research project. In this connection, no formal hypothesis is defined at the beginning of the research. Data that is related to the collaborative design activities of shopping centre refurbishment projects, has been collected and analyzed using the technique of analytic induction. According to Fellows/Liu, analytic induction is a step-by-step process of iteration and evaluation. Initially, the issue is defined and potential explanations and relationships are developed. Further instances or samples are investigated to analyze how well the hypothesized explanations and relationships apply. Such iterations continue until the hypotheses suit what is found in the data at a suitable level of statistical significance in appropriate cases.

The approach of analytic induction echoes Bono's view with regard to the analysis of data. Bono considers that the creator of new ideas must do a lot of "idea work" in his or her mind and then check out these ideas against the data, just analyzing the data is not enough [Bono, E.D., 1990]. The documented procedures described in the existing system and design records of typical projects will be the instances or data set against which different ideas are checked. Besides existing data, concepts that have been established in previous research with regard to the application of hypermedia for preliminary building services design will be tested against the data [Lee, Y.C., 1995]. Ideas from other researchers into hypermedia will also be examined with a view to supporting or refuting explanations of the latest data set.

The extent of the research is broadly broken into two main streams:

- the collaborative design process on the refurbishment of a shopping centre and
- the characteristics of hypermedia in managing design information in a collaborative manner.

The first item covers the activities that range from the incipient conceptual design to the conclusion of a client's brief when detailed design is about to commence. The delineation of these research boundaries is based on the perception that all subsequent design, whether it is a tender drawing or a specification, hinges on the client's brief. It means that any dispute over the appropriateness of a design item will be interpreted with reference to the client's brief in a way similar to the situation where a building design is checked against a building code. In other words, the entire refurbishment project is governed by a client's brief and this forms the basis for all subsequent information management protocols. However, the activities and processes under investigation will be confined to those adopted by the Hong Kong Housing Authority for two reasons. First, collaboration patterns may differ in different organizations that have dissimilar cultures. Consequently data collected from other organizations could result in an over-complicated mission, difficult to manage within the scope of a single research project. In addition, the commercial portfolio of HKHA is itself significantly large to justify dedicated research independent of other undertakings.

The second item requires much elaboration regarding the exact meaning of hypermedia. In its simplest form, hypermedia may be considered as merely hypertext that provides non-linear connection between pure text documents. The recent proliferation of the World Wide Web (www) has triggered debates on whether www is treated as a hypermedia system or not. Immediately it gives rise to the question that should the choice of the Internet environment be included in this research project? In order to limit the scope of the research within reasonable boundaries, the investigation will, initially, be limited to exploring the most basic form of hypermedia first. Subsequently, the relevance of the Internet will also be examined.

1.4 Literature survey

The literature survey is carried out in line with the two main streams that have been defined for the scope of the research project. Therefore, the first two keywords to be searched are "collaboration" and "hypermedia". The search is extended to words and phrases related to "collaboration" including collaborative design, concurrent engineering, etc. "Refurbishment" is also searched, which brings the study into another area about life cycle costing. References to complex problem solving, agents and system thinking have been discovered. Concepts identified from these references play a pivotal role in the formulation of the problem.

With regard to hypermedia, related terms that have been searched include hypertext, multimedia, HyperCard, authoring tools, etc. The combination of these two main streams of search did result in papers that cover both areas but the resulting number is relatively small in comparison with those addressing the conceptual modelling of hypermedia data. Search results when combining the term hypermedia and building services engineering and/or refurbishment was limited. The literature survey also indicated that little work has been undertaken in the building services engineering field with a direct relationship to the research project. As a result, the area of search is broadened to cover experiences from other applications, such as decision-support systems.

CHAPTER TWO

Chapter 2: The design process of building services engineering systems for refurbishment projects

2.1 Design philosophy

Shopping centres comprise a diverse range of building services engineering systems, such as electrical power supply and distribution, lighting, air-conditioning, vertical transportation, fire services, water pumps and plumbing, security, public address, telecommunication, etc. Major maintenance and replacement of these facilities is a nuisance and is a cause of great disruption to the tenants and customers of the shopping centre. The life expectancy of different systems frequently vary. Therefore it may not be viable to schedule the replacement work in such a way that all work will be carried out within the same period although this would minimize disturbance. As a result, the building services engineering systems are normally refurbished as a single project independent of other trades. Under such circumstances, the design building services engineer (BSE), who plays an active role in the refurbishment process, will produce a design that is mainly system- or distribution-oriented with minimal co-ordination with the building's fabric. This lead to little or no significant collaboration effort between the BSE and other professional disciplines who also contribute to the operation and maintenance of the shopping centre.

Notwithstanding that the BSE may have his own agenda for maintaining building services engineering systems, it is inevitable that for larger scale refurbishment work, other contractors may be involved. In most cases the building work contractors co-ordinate with the building services contractors to provide building supporting work [Kwok, S.T. and Lee, Y.C. 1998]. The fact that each building services engineering system would require a specialist contractor further complicates the co-ordination problem. The relationship between the working parties may be characterized as 'many-to-many mapping'. For example, the fitting-out of false suspended ceilings requires the close liaison of contractors of four different trades including the false ceiling specialist, air-conditioning, fire service and electrical contractors. The co-ordination of the respective contractors mainly focuses on the programme of their work as well as the actual construction details. However, all these efforts will fail if the design concepts of the architect and that of the building services engineer do not tally. In this particular case, the designed purpose of the area under the false suspended ceiling will dictate the lighting layout which in turn dictates the type of air-conditioning and fire services. This information should be precisely conveyed to all design team members during the early design stage.

Evidently the BSE has to liaise more closely with other works professional in the case of a major refurbishment project for an entire shopping centre. The design intent as well as the justification for any proposed modification to the existing design of a shopping centre has to be explicit in order to ensure there will be no conflict between the different systems. In other words, refurbishment of a shopping centre strongly exhibits features that warrant the adoption of a collaborative approach.

As far as a BSE is concerned, his primary task is to provide an adequate level of services commensurate with the intended purpose of a particular area within the built environment, in this case a shopping centre. It is noted that building services engineering design is governed by various well established design guides, regulations, codes of practice, etc., such as the IEE Wiring Regulations [The Institution of Electrical Engineers, 1991] and LPC Rules [Loss Prevention Council, 1999]. Junior engineers who may lack experience and confidence frequently adopt a "black box" approach when applying design softwares of these design rules [Gilleard, J.D. and Lee, Y.C., 1996]. For example, they may only focus on the correctness of the calculations of the building services engineering systems in respect of these rules yet miss the major target, i.e. to satisfy the design intent in relation to the purpose of a building, or the project objective. Thus, the client's satisfaction would be undermined when a BSE has a perspective different from those of a project architect and other project team members regarding the intent of a design, Figure 1. Clearly there is no simple way to assess how much a design engineer understands the project's objectives. Not until the day when something goes wrong will such misunderstandings and shortcomings be uncovered.

The traditional practice of adopting ruled-based or parametric design techniques by a BSE has been reviewed and critiqued in previous research [Gilleard, J.D. and Lee, Y.C., 1994]. It has been found that the representation as well as the interpretation of the design intent of conventional design softwares is inadequate. It is also suggested that BSEs should dispel the feeling that they are systems designers who simply fit engineering services into the preformed shell [Berry, J., 1995]. The fact that decisions by other disciplines have a major impact on BSE's work is often overlooked. The situation is further aggravated in the case of refurbishment projects of larger scales where the client's requirements may not be well defined at the outset of a project.

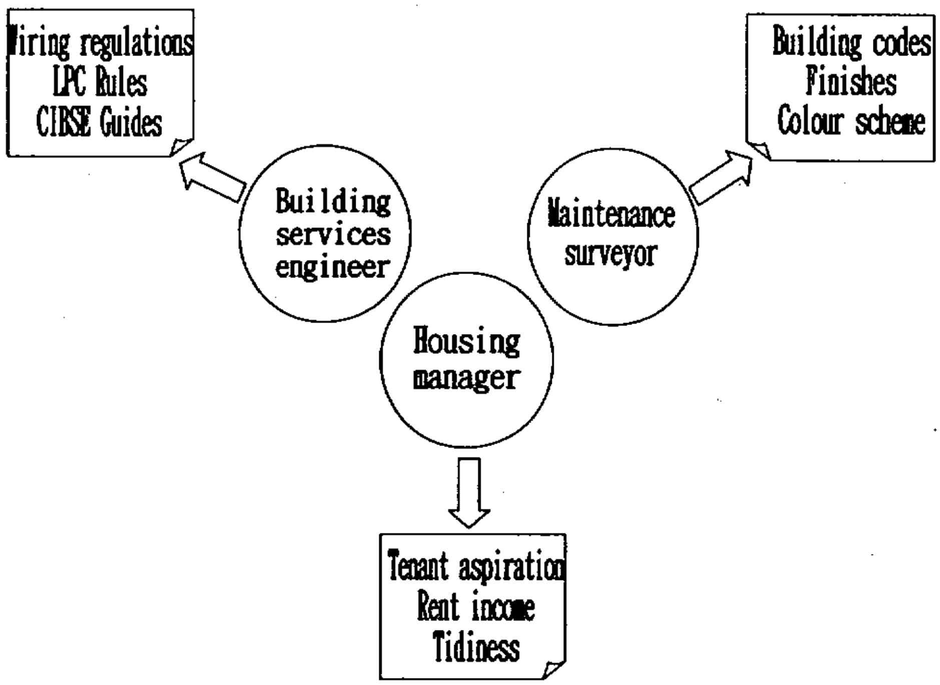
The above arguments suggest that the traditional design philosophy adopted by a BSE may not be able to survive the complex situation encountered in refurbishment projects, in which the design problems are not adequately defined. BSE typically works with design codes and rules, which are readily accessed through many commercial software packages and computer-aided design tools. These tools can handle complicated mathematics and iterations for well-defined algorithms. However, they may become ineffective when managing information in complex and weakly structured domains typically seen in refurbishment projects. In contrast, a hypermedia advice system has been proposed against the requirements of the "kiosk systems" where the information are found within complex and weakly structured domains [Beane M., et al., 1996].

It is therefore suggested that hypermedia could be an alternative paradigm, e.g., a computer-aided tool may be developed to assist a BSE in handling collaborative design tasks typically seen in refurbishment projects. In this connection, the design activities of a project team in Hong Kong Housing Authority (HKHA) are studied. This team is responsible for the refurbishment of the shopping centres managed by HKHA. The analysis is focused on the preliminary design stages, i.e. from the feasibility study to tender document preparation. The relationship between a BSE and other project team members, as well as the information flow, is critically examined.

2.2 Design procedures

2.2.1 Design considerations

The HKHA is the largest landlord in Hong Kong in terms of the total area of retail space. It has a portfolio of over 110 shopping centres as indicated in Section 1.1. The internal floor area (IFA) of each centre ranges from a few thousand square metres to over ten thousand. Many of these centres were built decades ago when the Hong Kong Government started to develop new towns in the sub-urban areas. Some of them are located strategically along main traffic routes such as railway lines and therefore business is good. However, most of them are designed to serve local residents without any significant inflow of customers from other areas. It is not uncommon to see that many facilities deteriorate and the shopping centre designs seem outdated in comparison with the recently completed ones. Consequently, business turnover of these shopping centres tends to reduce. Hence, the HKHA has a policy of regular scheduled refurbishment projects basis in order to maintain their commercial viability.



Project team members with different perspectives of project objectives.

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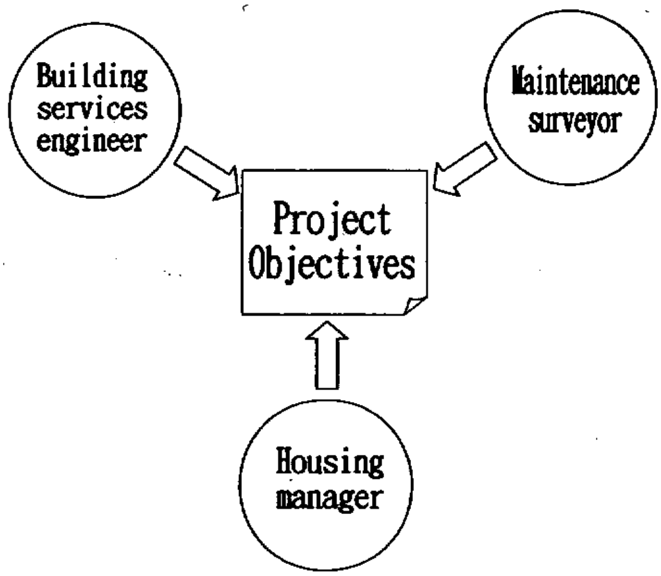


Project tean members share common project objectives.

Figure 1. Different perspectives of project objectives.

Being a government body, the HKHA has to be accountable to the public with regard to the policies that govern the management of these shopping centres. Questions have been raised from time to time as to why a certain amount of money is spent on one shopping centre and not on others. HKHA top management has a strong desire to operate these shopping centres in full compliance with the business norms of the private sector, i.e. no subsidy to the shop tenants. However, the HKHA has found it very difficult to convince the public that 'business-is-business' and the HKHA has no social obligation to bear the risk of any loss to the shop tenants arising from the changing commercial world.

In this connection, any refurbishment proposal has to fulfil criteria in at least two major aspects, i.e. commercial viability and consistency with the social norm expected of HKHA. Clearly these two elements may conflict with each other and as a result the outcome of a refurbishment proposal might not be precisely predicted during the planning stages in terms of the final scope of work. For example, where it is suggested that a central air-conditioning system be provided to an existing shopping centre which has been designed with natural ventilation in common areas and tenants providing their own air-conditioning systems. The purpose is to enhance its competitiveness with neighbouring commercial premises. Obviously tenants have to pay an extra charge to cover the air-conditioning cost. There are cases where tenants denied they were obliged to share these costs fully, and where the politicians were more than happy to support the tenants' stance. As a result, the refurbishment plan had to be modified by deleting the air-conditioning option in order to maintain the commercial viability of the refurbishment plan. The requirements of the project are normally summarized in the form of a client's brief. Because of unpredictable changes, tracking of the design variations is possible only when a client's brief has been clearly documented.

2.2.2 The client's brief

The HKHA was the first Government Department in Hong Kong to acquire ISO 9000 certification in respect of its quality assurance systems in the construction and maintenance of public housing [Gilleard, J.D. and Lee, Y.C., 1998a]. Procedures of all major works relating to the design, construction, operation and maintenance of housing are stipulated in the form of quality manuals. These manuals clearly identify procedures regarding the responsible persons, the purpose of an action, the approving authority, etc. Such documentation attempts to ensure a consistent performance of an individual officer irrespective of his experience and background. On the other hand, these procedures may be seen as a management tool that could be harnessed by the top management to monitor the proper implementation of their policies. As far as refurbishment of shopping centres is concerned, the monitoring is realized through a three-tier authorization hierarchy, which is responsible for the vetting of a client's brief.

The three-tier system comprises:

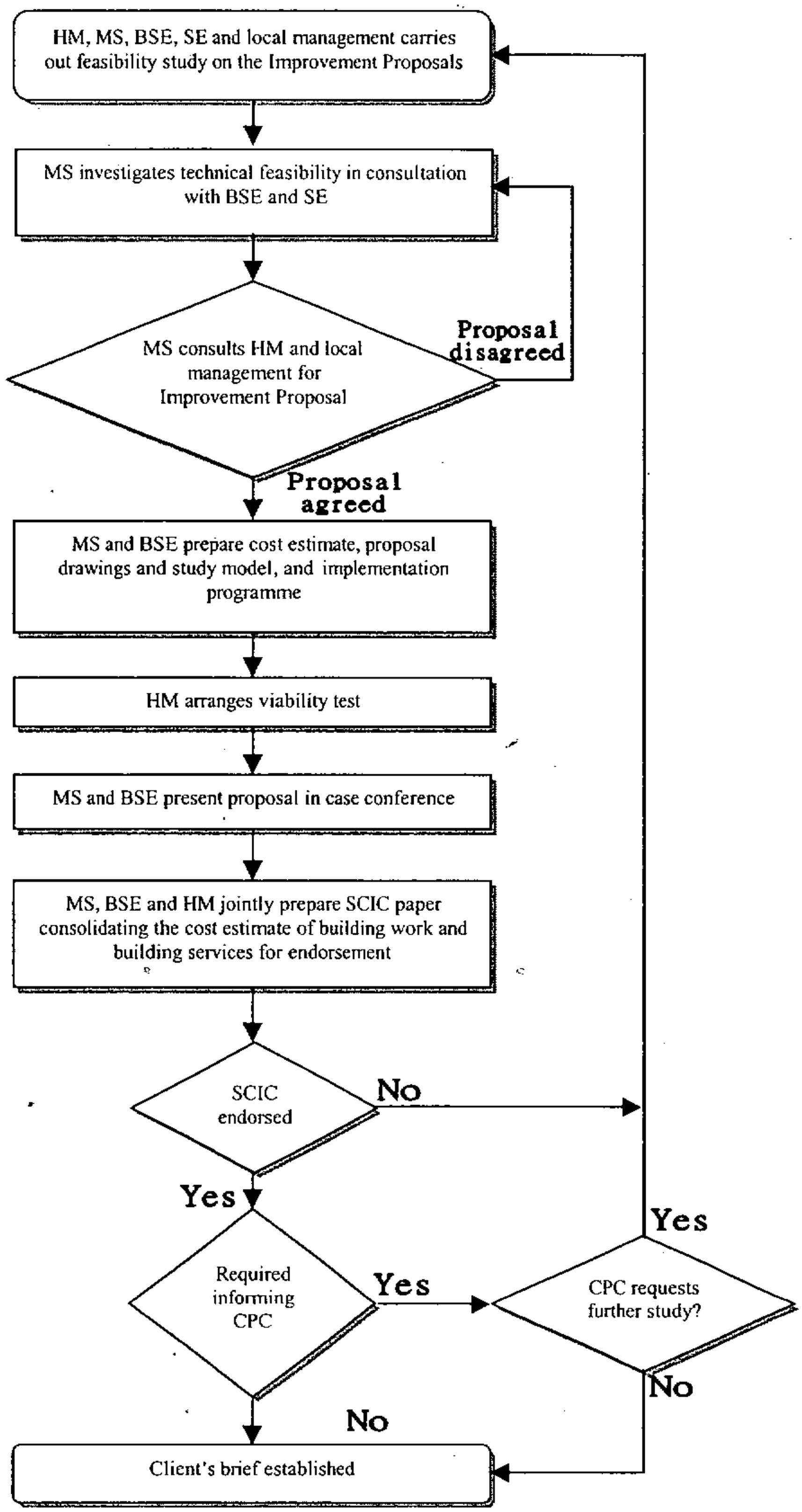
- the case conference in which all project team members meet to agree upon all major improvement items,
- the Shopping Centre Improvement Committee (SCIC) who endorse the improvement proposal as agreed in the Case Conference. SCIC is represented by top officials of HKHA, and
- the Commercial Properties Committee (CPC) which would give final approval to the improvement proposal and is made up of members appointed from the private sector in addition to top officials of the HKHA.

Once the SCIC and CPC have approved the client's brief, any subsequent amendments to it may not be implemented without going through the same authorization cycle again. Obviously such an arrangement is not ideal in terms of the flexibility necessary for any project in which project conditions may be prone to frequent alteration. Therefore, a client's brief could be regarded as a constraint set against the design of the project team on the one hand, and it may act as an agent to facilitate the collaboration of the project team on the other. In other words, all project team members can work on the brief together. This allows everyone in the team to visualize the project objectives and design intent more clearly. In consideration of a pragmatic approach in resolving the lack of flexibility of the three-tier authorization system, the project team should endeavour to improve the quality of the information represented in the client's brief. That is to say, if SCIC and CPC members are able to understand the background and justifications of any proposed change to a design brief, they will approve it more readily. As a result, the project team might be more effective in responding to design changes.

2.2.3 The work flow

The authorization process of a client's brief under the three-tier system is shown in Figure 2 which is documented in the quality manual of HKHA. Besides the building services engineer (BSE), the project team (PT) is also made up of representatives of other disciplines such as the maintenance surveyor (MS) and the structural engineer (SE). These three disciplines collaborate to advise the client on the condition of the existing facilities as well as the feasibility of meeting the client's requirements. The client is represented by the housing manager (HM). This process is in fact a subset of a master procedure that consists of four stages:

- feasibility study and scheme design,
- formulation of client's brief,
- detailed design and
- tender documentation.



Legend:

HM: Housing Manager MS: Maintenance surveyor SE: Structural engineer
BSE: Building services engineer CPC: Commercial Properties Committee
SCIC: Shopping Centre Improvement Committee

Figure 2. The formal work flow.

In a simple and straightforward case, the design work would progress through these stages in a linear manner as shown in Figure 3. However, it is an over-simplified picture, which is easily illustrated by taking a walk-through to a typical refurbishment project.

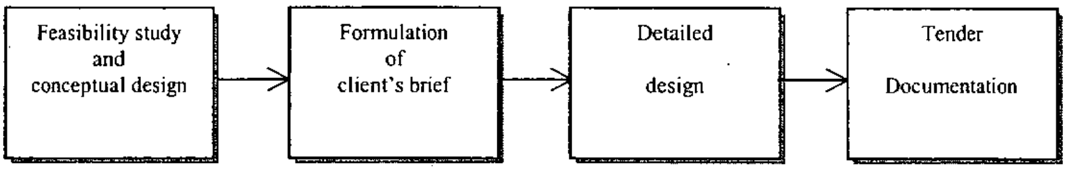


Figure 3. A four-stage design process.

Normally, the housing manager (HM) who represents the client, initiates a project by putting forward the client's requirements, which might include additional retail space and/or the addition of major new facilities such as central air-conditioning (A/C). Subsequently, the design team (BSE, MS and SE) responds to the HM's enquiry on the technical feasibility of retrofitting the centre. If the answer is positive, and subject to certain conditions being satisfied - such as an additional transformer room being constructed in order to meet the additional electrical loading arising from the new A/C plant- the work progresses. However, an opinion survey conducted by the HM might suggest that the majority of the shop tenants would decline to bear the extra cost of the central A/C. Therefore, in this case the client's brief submitted to the SCIC did not include central A/C. However, the decision of the SCIC suggested that the project team should revisit the option of providing central A/C with a view to maintaining the competitiveness of the centre in the next decade. Inevitably, the project team has to go through the authorization cycle again, Figure 4.

The four-stage process basically provides a macro view of how a client's brief is authorized as well as the major milestones in administrating a contract in the pre-construction phase. It does not show the relationship between the PT members regarding the way that they communicate with each other. The flow chart as shown in Figure 2 also suffers from a major drawback in that it lacks the representation of design intent. The system does not encourage clear articulation and documentation of the development of design concepts.

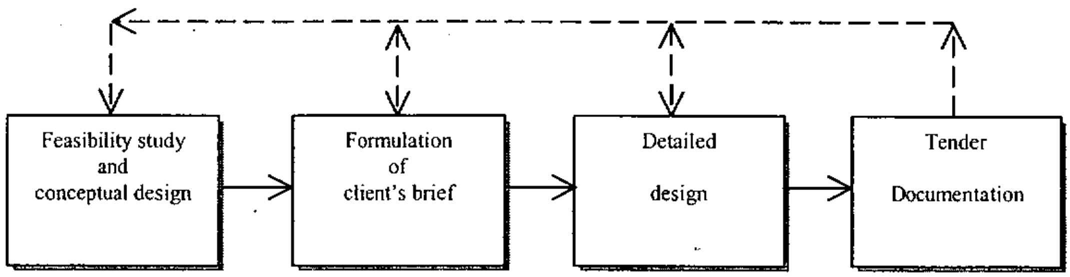


Figure 4. Backtracking of design activities.

2.2.4 Managing design changes

Changes in design are not rare in construction projects. For a new building, design change can be tracked relatively easily because all changes are based on a blue print that essentially contains all the project information and data. As for a refurbishment project, the lack of accurate information regarding the conditions of an existing building frequently gives rise to much uncertainty. So too the order in which the refurbishment work is undertaken. This uncertainty leads to confusion.

There are at least three factors that may undermine the PT to promptly respond to a request for design change:

- lack of survey data regarding the existing conditions of the building fabric and facilities resulting in poor quality of the design information,
- any change or variation of design to be agreed by all PT members: a time-consuming process yet critical to subsequent development of design and
- unpredictable change requests and very short response time allowance.

The key issue in handling these design changes is that any variation should be duly authorized. This is to ensure that they are not in violation with the principle laid down in the client's brief approved under the three-tier system. As such, the poor quality of design information could delay the PT checking the proposed design change because more time is required to verify any information from an unidentified source. The need to consult all PT members further complicates the process because different design options may arise from having to incorporate comments from various members. A change request taking place in an unpredictable manner or with a minimum of advance warning imposes tremendous pressure on PT members. Short turnaround time also leads to higher chance of making a wrong decision. Moreover, the situation is more acute if the project is at a very late stage when information proliferates and tracking a specific information item is much harder.

2.3 Financial considerations

Using inconsistent information (or misinformation) frequently causes two major problems. First, extra project time is required in order to rectify any work undertaken which is not in compliance with the approved brief, i.e. abortive work. Second, such abortive work incurs extra cost because it is not the contractor's fault and therefore a variation order has to be issued. The delay in completion also has indirect cost implications. Where additional retail space is to be built in the refurbishment project, the delay would also give rise to loss of rental income.

For example, assume a refurbishment project will provide an additional retail space of 2,000m^2 at a project cost of approximately $90 Millions Hong Kong Dollars. The estimated rent level is $300/$m^2$. Therefore, upon the completion of the project, the shopping centre in question will have an additional rental income of $600,000. per month. When a project is delayed by six months, the total loss in rental income will be $3.6 millions, which is equivalent to 4% of the total project cost. The actual loss could be higher if the cost of the abortive work is taken into account as well.

Conversely speaking, if the overall project cycle time can be shortened, there is a financial gain by virtue of earlier intake of the new retail space, i.e. advanced rental income. Broadly speaking, the cycle time of a refurbishment project is about three to four years depending on the scale of the work. Assuming the construction time required is fixed, the only way to advance the project completion date is to improve the efficiency of the project planning, i.e., complete the four-stage design process earlier. In principle, this can be achieved by minimizing the amount of backtracking under the four-stage process and the three-tier authorization system. Alternatively, introducing an effective processing system for design changes would reduce turnaround time and possibly eliminate abortive work where practicable.

2.4 Common faults in processing design information

Any faults in the processing of information may lead to a delay in awarding a contract and/or completion of a project. The actual occurrence of these faults can vary in different situations. For the purpose of this research project, the generation and recording of design and project-related information, which is to be analyzed, is confined to the pre-construction phase. Nevertheless, it is obvious that the adverse effect of any incorrect or poor quality information arising during the pre-construction period will certainly be reflected in the design stages as well as the subsequent construction stage. Shortcomings occurring during the design stages normally have a less unfavourable effect provided they can be checked during the four-stage process, i.e. there is still float time to change a design. A typical example is the missing or incorrect setting of the builder's work requirements for major building services engineering equipment. This can still be resolved if an appropriate amount of "prime cost sum" has been allowed in the main building contract. There are also cases where the building layout has been changing so frequently and abruptly that the BSE may have adopted a wrong version in preparing his own drawings. This sort of fault happens more frequently at the end of the design stages when the amount of design information multiplies.

If incorrect design information is left unnoticed until the very late stage, e.g., when the final completion date is imminent, the situation will be critical. For example, in one recent project a water feature had to be overhauled during the improvement of a shopping centre. The main contractor mistakenly removed the whole water feature. This work was never endorsed by the three-tier authorization system. However, the project team has no choice but to seek retrospective "covering" approval. On the other hand, if a project has to be inspected by the Fire Service Authority prior to formal completion, the crucial design information lies in the consistency in the building plan submitted to the Fire Service Authority against the as-built layout. Any failure in the inspection would again delay the project. Another example is where a building that has been built in full compliance with the fire service regulations. However; part of the premises being built have never been shown on the building plan submitted to the authority. As a result, the Fire Service Department inspection is failed because of the inconsistency regarding which part of the shopping centre is to be included in this improvement project and the subsequent inspection. Such shortcomings may happen when an improvement project has been carried out over a prolonged timeframe, which is usual practice for refurbishment projects because work sites cannot be readily available unless proper arrangements are made to settle the sitting tenants. Clearly such a problem can be easily solved before hand if a correct client's brief is available to the project team.

2.5 The problem

The behaviour of a BSE has been analyzed in the carrying out of design tasks. For system- or distribution-oriented design (typically seen in projects for replacement of building services engineering systems only), the BSE main challenge is to satisfy the established design codes and rules, to which he is accustomed. As regards major refurbishment projects such as those encountered in shopping centres, a BSE may not be adequately equipped to collaborate with other parties of a project team. He may have to adjust mind set that prevails in traditional building services design work, i.e. designing in isolation from other disciplines. Also, he lacks the tools that would enable him to organize design information and the subsequent sharing of this with his counterparts. An appropriate tool or protocol is necessary to rationalize the authoring as well as management of the design information in consideration of the cost benefit arising from the possible reduction in the project cycle time.

CHAPTER THREE

Chapter 3: Collaborative design and hypermedia

3.1 Primary information elements

It has been stated in Chapter 2 that the request for design change may arise in an unpredictable manner. As such, it may not be possible to construct a model that might predict any of these changes accurately. Clearly, the flow of information among project team members as well as that between different stages of the design process, is not sequential. It gives rise to the hypothesis that the flow of design information in collaborative design environments may be readily represented in hypermedia, which is understood to be an effective medium for organizing non-linear information flow. To this end, it is necessary to identify what are the information, different types of information and their relationships, specific patterns in the exchange of information, etc.

As mentioned previously, a BSE normally focuses his design work in compliance with rules, regulations and standard specifications. Naturally, these become the first batch of information to be managed by a BSE. Also, he has to conduct a condition survey for the shopping centre that is to be refurbished. The conditions of the facilities and building fabric would normally not have any drastic variation during the design period. Hence, the survey data is typically considered as a constant. However, the norm and expectation of the community may have implications for a decision regarding the standard of finishes and types of facilities to be provided. The norm should be fairly steady within a certain period of time. These three batches of information share one common feature, i.e. they can be seen as background information that will remain fixed within the design period.

Fixed data is basically static and can be termed 'standard information' that is unlikely to be tampered with by other project team members. However, a BSE has to receive and consider proposals raised by other PT members. Hence, the proposal is checked against the fixed data or standard information, which forms the basis for the BSE to determine specific design requirements. Improvement proposal may have to be modified in order to satisfy some constraints arising from the specific design requirements. When the design of the refurbishment plan is developing, the proposal essentially becomes a variable data set. Clearly there are two distinct types of information elements by virtue of their change status relative to a BSE, i.e. the fixed and variable data sets. By connecting the elements as previously described, a basic information model can be constructed to represent the primary activities that a BSE would carry out in his collaborative design process, Figure 5.

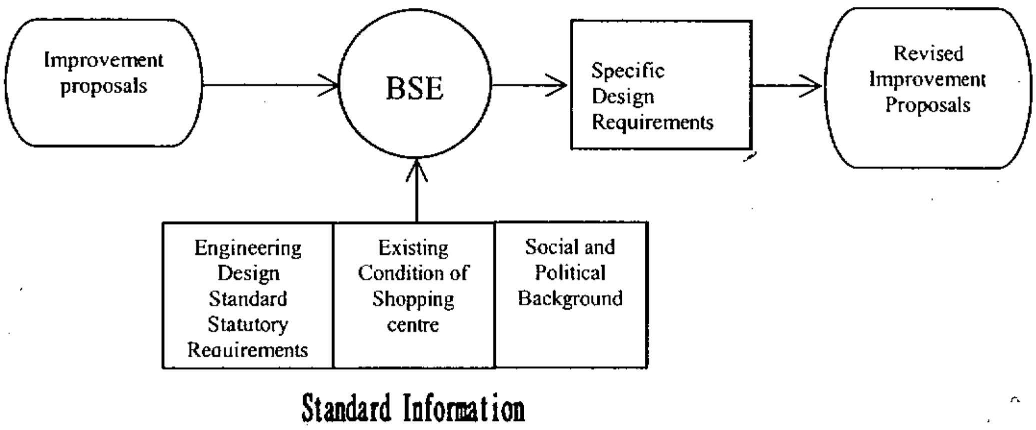


Figure 5. The basic information model.

The development of the basic information model may result in a framework that represents the design intents as well as the project objectives. Hitchcock proposed a similar model for life cycle costing of building where three primary informational elements are required to represent the design intent: project objectives, a product model of the design and design context assumption [Hitchcock, R.J., 1995]. Project objectives are the stated performance goals that a particular building design is attempting to achieve. The product model is a complete detailing of the physical components of a building and dynamic operation of the building systems such as the air-conditioning control system. Context assumptions define the operating environment within which the building has been designed to achieve the stated objectives, such as design cooling load to size an air-conditioning system.

The proposed basic information model resembles Hitchcock's model. The improvement proposal plays a role similar to that of the project objectives by defining the expected results of a refurbishment project, i.e. the performance goal. Both the standard information and contextual assumptions set the constraints as well as boundary conditions of the new design. Finally, the specific design requirements are comparable to the product model, which is the most explicit representation of the proposed design prior to the completion of the tender documentation stage.

A simple example illustrates the concept of the basic information model. A client's brief typically states: "to provide central air-conditioning to all common areas of the shopping centre". This statement can be categorized as an improvement proposal or project objective under Hitchcock's definition, which forms a part of the variable data set. On the other hand, the weather data, cooling load assessment formula and environmental constraints on the selection of a chiller plant are the fixed data set or standard information having an equivalent purpose in the design context assumption. The improvement proposal must be validated against the standard information before the specific design requirements can be determined, and in this case, the location and size of the proposed chiller plant (the product model).

The proposed BSE basic information model can be adopted by other project team members as well. The exact content of the elements of the model for respective PT members may vary. Yet their functions are essentially the same. Clearly these models must be connected in one way or another. The quest for these connections has to be conducted in a more global manner in order to obtain a picture that may reflect real situations more closely.

3.2 Collaborative design and complex problem solving

The connections or relationships between basic information models of respective PT members have to be identified. Notwithstanding the similarity of these models, each PT member will undertake a decision making process based on his understanding of the project requirements and, very often, according to his own practice. It is generally agreed that decision making is a goal-directed activity that involves a wide range of cognitive operations and that the specific process and strategies employed by individual decision makers can vary widely [Frensch, P.A. and Funke, J., 1995]. As far as a refurbishment project is concerned, the approach adopted by an individual PT member in resolving an agreed improvement proposal with other member may not be readily defined. Such uncertainty is also seen in many other problem solving situations, which Pohl would treat them as "complex problems" [Pohl, J., et al, 1997]. Pohl advocates 'serious' development in computer-based decision-support systems to assist decision-makers to face the challenge arising from the dynamically changing conditions typically seen in complex problem situations.

Pohl has also suggested more than half a dozen functional features that a computer-based system should have in resolving complex problems. The most outstanding feature is that flexibility should be built into the user-interface so that the human-computer partnership can evolve in directions and capabilities that cannot be predetermined at the outset. His rationale is that "*The human decision maker brings a complex interplay of many cognitive, motivational, personal and social factors into the human-computer partnership. Most of these factors are poorly understood…that are still largely undeciphered.*" [Pohl, J., 1997]

A refurbishment project may be characterized as is a complex problem where "*the complexity of design does not appear to be due to a high level of difficulty in any one area but the multiple relationships that exist among the many issues that impact the desired* *outcome.*" [Pohl, J., Myers, L. and Chapman A., 1994]. If flexibility is the answer for a complex problem, the next question is how flexible should a computer-based system be? A simple answer is that a "canned" design solution is definitely not suitable or where the problem is well defined. For example, assume complaints have been received stating that "the room is not bright enough". The "canned" solution would be to input the dimensions and the required illumination levels and the quantity of lighting fixtures according to a predefined algorithm. However, very often the problem of poor illumination can be attributed to many other factors such as the deterioration of the lamps, dusty walls that reduce reflection of the light, user's expectation, etc. Conventional design software packages can by no means exhaust all the factors, whose numbers are never known in real situations, Figure 6.

It can be seen that even for a very simple problem, the number of solutions tend to proliferate as the number of factors to be considered grows. These factors are in fact the manifestation of the partial real-world conditions. The perception that real-world problems are frequently complex and less well defined is also shared by Checkland and Scholes:

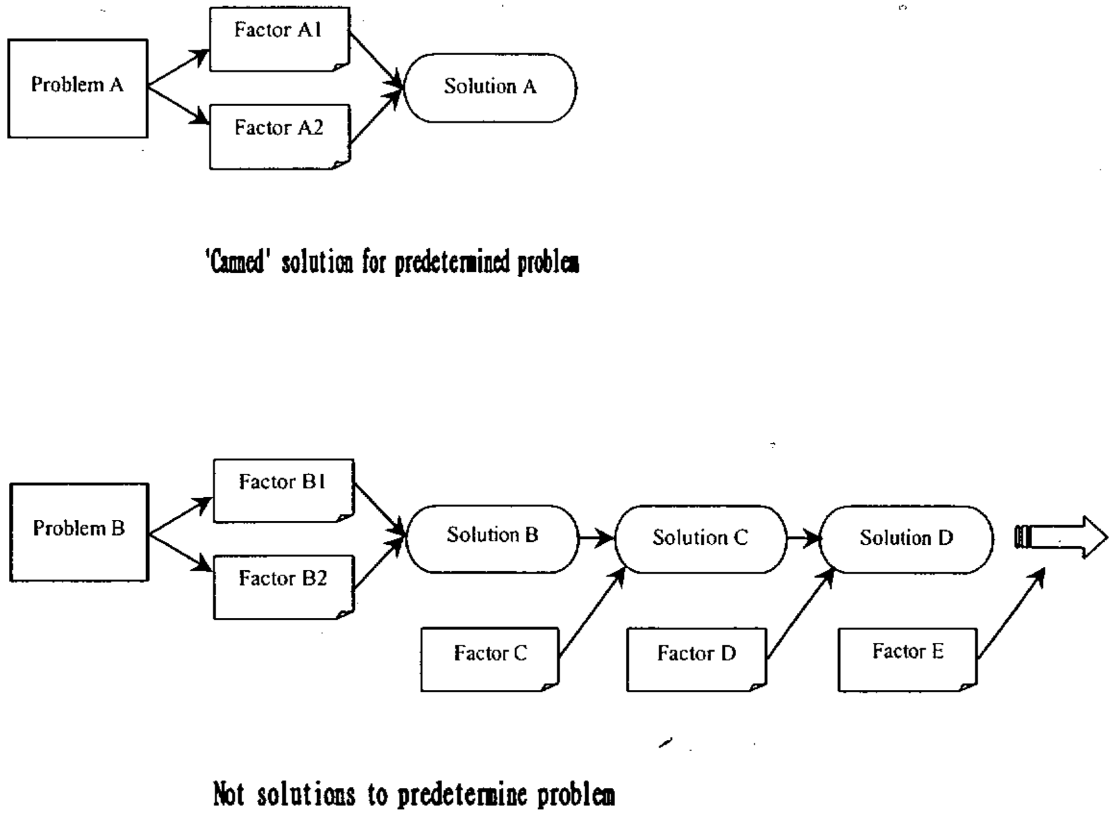


Figure 6. "Canned" solution of a problem vs. Solutions for a changing problem.

3.3 Real-world situation

The soft system methodology (SSM) theory suggested by Checkland helps to organize 'messy' real-world situations. SSM is promised on the basis of system thinking: "*'the system' is no longer some part of the world which is to be engineered or optimized, 'the system' is the process of enquiry itself*" [Checkland, P. and Scholes, J., 1990]. SSM is highly defined and described but is flexible in use and broad in scope. Checkland argues that the 'sensible user' of SSM will involve other people in problem solving. SSM is intrinsically a collaborative approach. As such, from the perspective of SSM, the refurbishment of a shopping centre may be seen as the defining of a methodology to model a collaborative design process that lacks a regular form.

According to SSM, 'purposeful activity systems' of the problem under consideration have to be named. These are termed 'root definition' expressed as a transformation process in which some entity, the 'input', is changed, or transformed, into some new form of the same entity, the 'output'. A model of the problem is derived from the root definition, which can be compared with the real-world situation. The root definition is made up of six elements:

C	customer	the victims or beneficiaries of T
A	actors	those who would do T
T	transformation process	the conversion of input into output
W	Weltanschauung	the worldview which makes this T meaningful in context
O	owners	those who could stop T and
E	environmental constraints	system which it takes as given.

A model to establish the CATWOE specific to this situation or the root definition of a refurbishment project may be developed. The root definition stipulates the core purpose of the activities system. The core purpose is represented in a transformation process which transforms 'input' into 'output', both of which are of the same entity but in different forms. Therefore, in SSM terms, an existing shopping centre that is deteriorating (input), through a refurbishment project (transformation process T) becomes a brand new one (output). However, this 'T' is not meaningful enough as it lacks the reason why a brand new shopping centre is necessary. As discussed in Section 2.2.1, a refurbishment proposal has to satisfy two major criteria, i.e. commercial viability and consistency in social norm as expected of HKHA. In this connection, there are at least two further scenarios of 'T' other than the one just mentioned, Figure 7. The first one is clearly the main concern of HKHA. Commercial viability could mean that HKHA will recoup every dollar spent in the refurbishment of a shopping centre by virtue of increased rental income. A trivial case of commercial viability is that the scale of the refurbishment is so small, avoiding any risk of failure to secure additional rental income, that the project can only be considered as maintenance work instead. Therefore, the first scenario may not be able to convey the full meaning in respect of the purpose of upgrading the shopping centre.

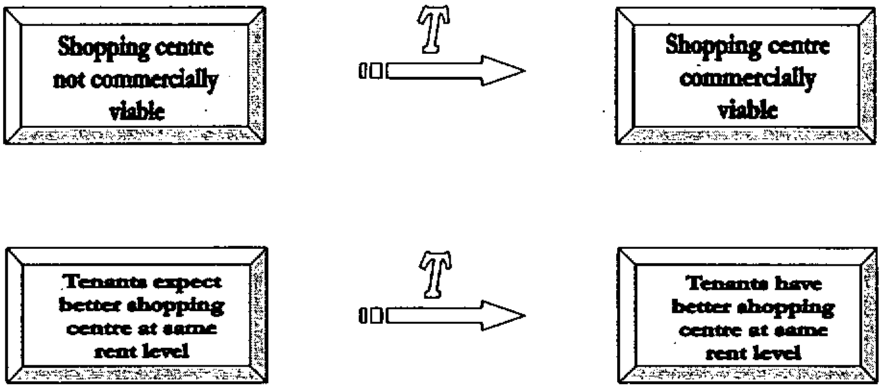


Figure 7. Two different scenarios of 'refurbishment project'-*T*.

The second scenario is entirely from the perspective of the tenants and is very unlikely to be the only idea to be adopted. Nevertheless, these two different ideas share one common goal, i.e. to keep the cost of enhancing the attractiveness of a shopping centre as low as possible. Clearly both HKHA and the tenants may enjoy a 'win-win' situation if the overall project cost can be lowered. Therefore, a critical goal is identifying activities that contribute to any saving in money terms. It corresponds with the argument, as articulated in Section 2.5, that the problem is to make available an appropriate tool or protocol to rationalize the management of the design information in consideration of the cost benefit arising from the possible reduction in the project cycle time. Under such circumstances, the *'T'* may be redefined as follows, Figure 8

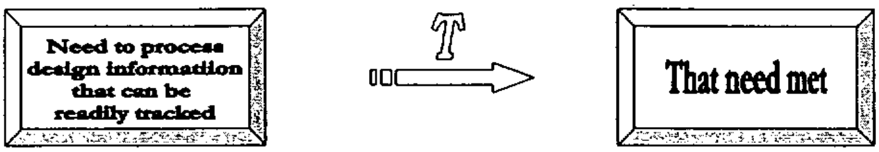


Figure 8. Alternative transformation process perceived.

In other words, the core purpose of all the project team members collaborating together is perceived as the acquisition of a design information set that can be retrieved more quickly in comparison with conventional practice. On the basis of the perceived *'T'*, other elements of the root definition can be determined.

The housing manager HM represents the client, and thus receives information/ services provided by the BSE. Yet, the development of a design brief inevitably involves all other PT members who assume the roles of sender as well as receiver of design information. Hence, it is justifiable to treat all PT members as customers 'C' as well as actors 'A'. The worldview 'W' of all members is represented by the three-tier authorization hierarchy explained previously. It is the most significant background to warrant the need of 'T'; i.e. enhanced information quality to satisfy the three-tier system.

By introducing the three-tier hierarchy into the root definition, it may be argued that the owner 'O' should be the Commercial Properties Committee (CPC), a group that has the final say in accepting or rejecting any client's brief. However, 'T' as perceived is not to pursue the approval from CPC. The primary function is to develop a set of design information that can be readily accessed. Since 'T' can be stopped by anyone from the project team - they rely on each other for the sharing of information-, 'O' should include all PT members.

Finally, there are many existing constraints that may impact the outcome of 'T'. In order to keep the argument simple, only those with the most profound effect are considered. The current design practices and procedures constitute the framework for the formation of a client's brief. It is not expected these will need any significant modification arising from the proposed 'T'. Therefore, these procedures are taken as 'E'. The root definition is summarized as follows:

- **C :** BSE, HM, MS, SE
- **A :** BSE, HM, MS, SE
- **T :** acquisition of design information set that can be retrieved more quickly in comparison with that of conventional practice
- **W :** the three-tier authorization hierarchy
- **O :** BSE, HM, MS, SE
- **E :** existing design practices and procedures

Thus CATWOE, perceived as a 'would-be' real-world situation, forms the theoretical reference for the construction of the model that describes how the information may flow throughout the collaboration process in preparing the client's brief. A different version of the CATWOE was discussed and presented during the early phase of this research [Gilleard, J.D. and Lee, Y.C., 2000]. In this earlier work 'T' has a different interpretation of the real world. Both definitions identify different parts of the world or reality.

3.4 Preliminary collaborative design model

From the establishment of the basic information model, the discussion has been directed to an appreciation of real world situations described by Pohl and Checkland, where one view is complementary to the other. The root definition represents the results of the analysis of the design activities of a refurbishment project at pre-construction stage. The common aspirations of both HKHA and the tenants in pursuit of a better shopping centre at a lower cost is contemplated in a different dimension, i.e. the study of design information flow in respect of the development of a client's brief. The SSM study has provided a clear focus with regard to the purpose and direction of further analysis. There are more sophisticated forms of SSM in respect of the construction of a process model. However, as far as this research is concerned, subsequent development is not directly related to the more elaborate SSM concepts, which are too specific when compared to the development of the proposed information system and model.

It has been argued that the BSE basic information model may be applicable to other PT members, at least in terms of its framework. It is accepted that the content within each primary information element of the specific basic model may vary. However, equally there are areas where they do overlap each other. For example, the 'social and political background' and 'existing condition of shopping centre' should be a common set for all four models. However, as far as the collaborative design activities or the perceived 'T' is concerned, the standard information or fixed data set does not play any active role in the process. It may be seen as the private area of the individual PT member, which can be segregated from the main information flow. If this is the case, the other two primary information elements (improvement proposal and specific design information) are the major 'ingredients' that constitute the flow. They are the 'variables' of the process and the algorithm that governs their development is not possible at this level of the study because each PT member is an individual decision-maker, who himself may not be able to predict his next move. It may be argued that the collaborative design work is essentially an authoring exercise that calls for original ideas and input. By no means does it resemble any thing like the games of playing chess or 'majong', which have highly defined rules of game. Under such circumstances, the number of alternatives that a player may choose for his next move can be calculated (by computers of course). In other words, the next alternative is to map out variable connections. It can be seen that all these variables will merge eventually to form the client's brief. Therefore, a preliminary collaboration model is suggested, Figure 9. The model is constructed by connecting all basic information related to PT members in a parallel configuration to form a close loop. The parallel arrangement implies that each PT member (to a very large extent) independently handles his own design during the collaboration process. On the other hand, a closed loop provides a mechanism to resolve disagreements. In theory, any 'revised improvement proposal' will be passed back to each PT member seeking approval/ alternative solutions.

However, the preliminary collaboration model does not suggest how the different improvement proposals may be combined into one solution agreeable to all members. By merging all the improvement proposals submitted by respective members, the combined proposal becomes a 'mixture' of proposals. This proposal may be unfeasible given the potentially conflicting ideas arising from the different 'ingredients' that have been mixed. However, the combined proposal forms the basis for subsequent collaboration between members on which further options will evolve. The improvement items contained in the combined proposal may also exist in three different modes with regard to the status of acceptance of these items that are suggested by respective members. These three modes are known as "complete agreement", "no agreement" and "no comment". The classification assumes that the data structure of the combined proposals is a simple one. That is to say, it may consist of a simple statement that may be readily assigned with a straightforward affirmative statement (or not). However, in reality, a proposal will consist of an array of statements that represent the improvement design.

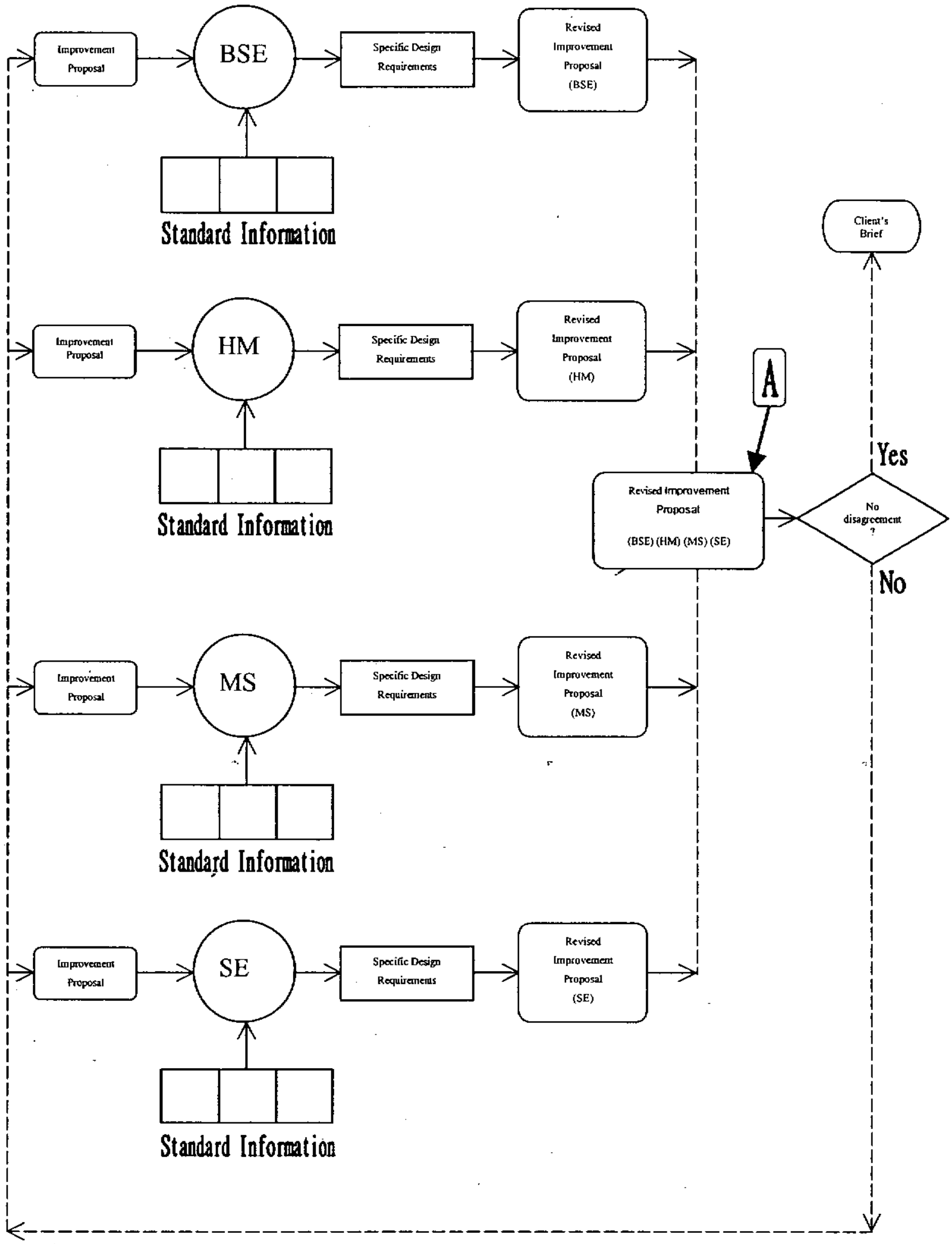


Figure 9. The preliminary collaboration model.

For the time being, a simpler version of the classification is assumed in respect to the three modes mentioned above. Referring back to Figure 9, ideally after one or more rounds of iteration, looping will stop as all improvement items in the combined proposal are in the 'complete agreement' or 'no comment' mode. However, in most cases the 'no agreement' mode will prevail despite iterative looping. Clearly the iteration has to be concluded somehow in order to meet target dates. (The simplest way to overcome such a dilemma is to invite the member's boss to dictate the decision.) Nevertheless, it may not be as simple as one would presume because the quality of the information may be poor as a result of the 'mixture' of the different modes of design information. The boss or the responsible person who is trying to judge the pros and cons of a design proposal, may be handicapped by the weak or even inconsistent opposition to a design proposal. Therefore, the most effective approach for moving forward is to rationalize these different modes of design information in such way that the iteration process may be better facilitated to enhance information quality or usability. In view of this, the characteristics of collaborative design are further examined.

3.5 Synchronous vs. asynchronous collaboration

The preliminary collaboration model can be seen as a snapshot of an evolving process. While showing the changing content of the design information, it does not show the relationship between the change in data content and the time scale. Obviously a combined proposal is meaningful only when the validity of an individual improvement proposal does not expire when a preset time limit has lapsed. That is to say, owing to the organic nature of decision-making activities, a member's proposal may be superceded by a subsequent one as the situation changes. Therefore, in checking the agreement status or the modes of the design information, the date of the information is a natural attribute that determines its validity. This is a crucial factor in ensuring the integrity of the final product (the client's brief), especially when the collaboration process is an asynchronous one, i.e. decisions are not made simultaneously.

In addition to time, the physical location of each respective design team member will affect the mode of communication, i.e. asynchronous vs. synchronous. So too the choice of communication medium. A time/space matrix has been suggested as shorthand to show the relationship for the various non-computer communication technologies with respect to time and locations, Figure 10 [Dix, A., 1998a].

	Same place	**Different places**
Same time (synchronous)	Face-to-face conversation	Telephone
Different time (asynchronous)	Post-it note	Letter

Figure 10. Time/space matrix.

The PT members are basically working in the same place, which is a typical arrangement for an in-house project team. It is also common practice to organize regular design meetings (face-to-face conversation), and forums so each member may table his design for agreement. In an ideal case the synchronous system enables a merging of the information flow from the four basic models at point "A" of the preliminary collaboration model provided an agreement can be reached for all design issues during the meeting. However, where each member's presentation is weakly connected to other design participants a longer time period is normally required when seeking a consensus. Time is usually not the driver and each member has sufficient time to document the three modes for the improvement proposal, i.e. complete agreement, no agreement or no comment). Therefore, the asynchronous system represents the behaviour of the collaborating team more closely.

It has been estimated that over 90% of the information flow between PT members is conveyed in a written form, e.g., memoranda, discussion papers, minutes of meetings, e-mails, etc. [Gilleard, J.D. and Lee, Y.C., 1998b], incrementally representing the conceptual design. The application of a synchronous system is limited. One distinct advantage of asynchronous communication is that there is no interruption to the work of a PT member who may pursue tasks in his own way. This gives greater autonomy and personal control [Dix, A., 1998a].

Time as well as place is a natural attribute of an information item. Both of those give rise to the concepts of synchronous and asynchronous communication. Nevertheless, in no way do they delineate the design concept. Their role is seen mainly as supporting a rationalized data structure or pattern of information flow. There exists some form of representation that depicts the design intent as a result of the cyclic implementation of the preliminary collaboration model. Evidently each implementation of the model should result in refinement or revision of the variable data set to cope with changing design requirements with a view to achieving the expected level of flexibility. Flexibility is one of the major criteria in solving complex problems as suggested by Pohl earlier. Pohl's answer to such a problem is a multi-agent computer-aided design environment.

3.6 Agents and flexibility

Pohl advocates the importance of providing flexibility in the user-interface in order to facilitate the human-computer partnership for tackling complex problems [Pohl, J., 1997]. Flexibility may be achieved by building computer-based agents in the process model so that solutions may evolve interactively. ("Agents" mean components of the decision making model that may involve a group - a committee, board, or design team - that are translated into a computer-based environment where the agents may reason or interact with each other or access a knowledge-base.)

The relationship between the degree of flexibility and complexity of a problem is not indicated in Pohl's work. The effort necessary to develop computer-based agents that can communicate with other agents, computer-based or human, is significant and has to be justified against the complexity of the decision-making problem. With refurbishment projects flexibility is required to track design decisions and (typically) subsequent refinements of the client's brief. Flexibility may also be perceived as the utilization of a sophisticated computer system that provide an intelligent means to obtain BSE results, e.g. the recognition of CAD objects (high level design representation) for the automated generation of air-conditioning ducts and pipes. With reference to a four-stage process for the pre-construction phase intelligent computer systems are mostly required at the Detailed Design Stage after layout plans have been developed. It is estimated that the amount of work with such an intensive computing requirement constitutes approximately 10% of the total project time at the pre-construction phase. Hence, it may be inferred that the contribution from these intelligent computer systems is not critical in enhancing the effectiveness of the collaborative design process as a whole. It may also be argued that an agent-based system may be developed to simulate the decision-making algorithm of respective PT members, such that the entire four-stage process is covered by the computer system. The feasibility for such a proposition is realizable only when each PT member reasoning (decision making) can be represented by explicit rule. However, uncertainty (in terms of cost as well as time) required for the acquisition of such a system has to be carefully considered prior to any serious development work.

The applications of agents are seen in two major areas: personal assistants and information-rich environments. The latter typically include enterprises and network information access. Enterprise application is similar to the case of the refurbishment project. It involves the updating of information. This process is qualitatively more complex than retrieval because it can potentially introduce inconsistencies. "*This is the province of workflow, a composite activity to solve some business need that accesses different resources and may involve human interaction.*" [Huhns, M.N. and Singh, M.P., 1998] Clearly human interaction is a major unknown if an agent-based system is to be implemented for a refurbishment project. A logical sequence is to establish those entities that can be identified using firstly a known methodology. Broadly speaking, the application of an algorithm to determine the information flow for a refurbishment project leads to yet another unknown. Under such circumstances it will be an almost impossible task to validate the integrity of the results.

In summary, an agent-based approach to meet the needs of flexibility is not considered valid. Firstly, the flexibility in generating new engineering data is insignificant with respect to enhancing the overall efficiency of the collaborative work. Secondly, human interaction uncertainty may corrupt the final research results. Consequently, a more pragmatic approach is to provide a tool or protocol as an information organizer that can capture and retrieve the decisions made by the respective PT members. This is contemplated in a computer-aided environment with anticipated flexibility. Previous research has demonstrated the appropriateness and feasibility of using hypermedia for the storage and retrieval of building services engineering design information especially at the preliminary and conceptual design stages [Gilleard, J.D. and Lee, Y.C., 1996].

3.7 Hypermedia

3.7.1 Background and history of hypermedia

An in-depth study was conducted of the application of computer-aided design and drafting (CADD) systems in the Architectural, Engineering and Construction (AEC) industry. The study investigated the divide between the engineer's mathematical design and the architect's need for "visual" interpretation. However, the initial study revealed that the application of intelligent systems such as an expert system for BSE design, was limited and that the integration of such systems with graphic-modelling programmes was not common in academic research. Further study into the approach adopted in BSE design also indicated that the design constraints were normally determined by building codes and formalized design rules. These rules and codes are by no means well structured and do not normally follow a sequential order. Under such considerations, hypermedia was chosen as a programming tool alternatively. The following sections summarize the background, history and theoretical basis of this research work. [Lee, Y.C., 1995]

The idea of hypertext was conceived in 1945 by Vannevar Bush who proposed a system called Memex ("memory extender"), which is described as "*a sort of mechanized private file and library*" and as "*a device in which an individual stores his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility.*" [Nielsen, J., 1990]. As the senior Science Adviser to President Roosevelt and administrator of the wartime Manhattan project, Bush developed his proposal for the Memex because he has worried about the explosion of scientific information which made it impossible for even specialists to follow developments in a discipline. Although the Memex system was never implemented, its concept is in fact the essence of modern hypertext systems.

In 1962, Doug Engelbart started his 'Augment' project to develop computer tools to augment human capabilities and productivity. This was the first major work in areas like office automation and text processing. One part of the Augment projects was NLS (for oN-Line System), which had several hypertext features even though it was not developed as a hypertext system. During the Augment project, the researchers stored all their papers, reports and memos in shared "journal" facilities that enabled them to include cross-references to other work in their own writings.

The actual word "hypertext" was coined by Ted Nelson in 1965. As an early hypertext pioneer, Nelson developed his Xanadu system. The basic Xanadu idea is that of a repository for everything that anybody has ever written and thereby a truly universal hypertext. When everybody can link with everybody else, there will be tremendous copyright problems if the traditional view of copyright is retained. Nelson's answer was to abolish traditional copyright to the extent that information placed in Xanadu will always be universally available. This principle may be feasible; the system would keep track of the original authorship and provide royalties to the original author based on the number of bytes seen by each reader. However, the Xanadu vision has never been implemented.

The early hypertext systems can best be seen as proof-of-concept systems showing that hypertext was not just a wild idea but could actually be implemented on computers and that use was mostly in-house at the same institutions where the systems were designed. Among other early hypertext systems that have been augmented with graphics are Hyperties, from the University of Maryland, and Intermedia, from Brown University, denoting the evolution of hypertext to hypermedia.

The most significant break-through in terms of popularizing hypermedia came with Apple Computer's decision to bundle a programme called HyperCard with new Macintosh machines. HyperCard offered users the ability to link text and graphics, to open external applications. For the first time, a really user-friendly, high-level programming environment was available for the Macintosh- with HyperTalk. HyperCard combined aspects of relational database models with the ability to integrate materials from heterogeneous external sources such as digitized audio and video.

The graduation of hypertext from a pet project of a few fanatics to widespread popularity was marked by the first ACM (Association of Computing machinery) conference on hypertext, Hypertext'87, held in November, 1987 at the University of Carolina, which was attended by almost everybody interested in the hypertext field. The first scientific journal focused on hypertext, *Hypermedia*, was published in 1989 by Taylor Graham.

3.7.2 Definition of hypertext and hypermedia

Ted Nelson explains: "*By 'hypertext' I mean nonsequential writing-text that branches and allows choices to the reader, best read at an interactive screen. As popularity conceived, this is a series of text chunks connected by links which offer the reader different pathways*", [Landow, G.P., 1992]. Hypertext is nonsequential without any single order that determines the sequence in which the text is to be read. Hypertext presents several different options to readers and the individual reader determines which of them to follow at the time of reading the text. This means that the author of the text sets up a number of alternatives for the readers to explore rather than a single stream of information. Brown University has another definition of hypertext: "*Hypertext is both an author's tool and a reader's medium. With hypertext software, authors or groups of authors will be able to link information together, annotate existing text, and create footnotes that allow readers to see either bibliographic data or the body of the referenced-text. Readers will be able to browse through linked, cross-referenced, annotated, footnoted texts in an orderly, but nonsequential manner.*", [Horn, R.E., 1989]. In essence, hypertext may be taken as an approach to constructing non-linear computer-supported materials and the term is also used to describe the materials themselves.

Hypertext is traditionally treated as a system for dealing with plain text. Since many contemporary computer materials include other media such as graphics, images and sound, some people prefer using the term hypermedia while others tend to use the two terms interchangeably. Hypermedia will be used in preference to hypertext throughout this thesis.

3.7.3 Nature and characteristics of hypermedia

There are at least three key characteristics of hypermedia software: (i) a network of nodes which may be text and/or graphics, (ii) software methodology that facilitates the building of and access to nodes via links and (iii) interface tools that facilitate the creation of arbitrary linkages in the text with buttons [Horn, R.E., 1989]. The network of nodes enables the user to conduct rapid browsing and navigation across the information space represented by the nodes. This is achieved by an effective user interface usually with a couple of mouse clicks or a couple of keystrokes. The link-node structure allows the information to be structured partially (semi-structured) or non-linearly (a non-sequential data structure), giving the user the freedom to associate various chunks of information,. These features of hypermedia are built on the three essential elements namely nodes, links and buttons.

Nodes are part of the hypermedia structure where the text, graphics, sounds or related information in the knowledge base are located. For some hypermedia implementations, a node contains one idea or one sentence; for other implementations the node may be a whole document as long as a book or chapter. So far the node is not a well-defined concept except in certain very structured contexts. Links connect nodes in the hypermedia software by computer-supported relationships that permit rapid and easy movement across the network of nodes. Buttons are specific locations in the hypermedia structure that permit the user to jump along a link to another node, usually with the click of a mouse. A simplified view of a small hypermedia structure is shown in Figure 11

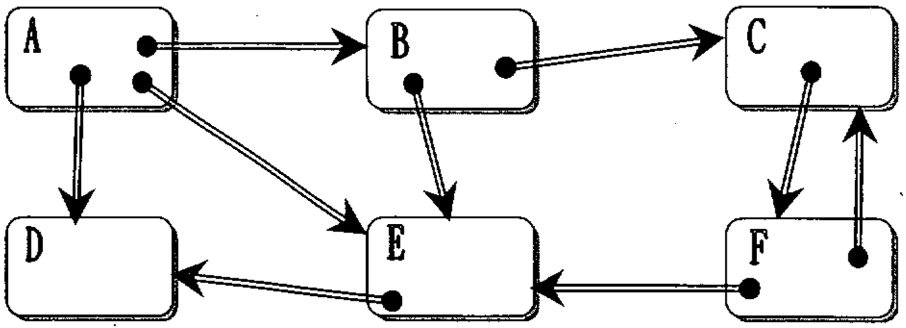


Figure 11. A simplified hypermedia structure with six nodes and nine links.

Hypermedia can be used to prototype the user interface for almost any other computer programme [Nielsen, J., 1995], because most initial prototyping consists of linking together screen designs and presenting them to the user in an order determined by simple user actions. In fact, HyperCard is regarded as one of the most well known and successful prototyping tools [Dix, A., 1998b]. Extremely simple prototypes can be constructed in any hypermedia system simply by linking together screen designs in the appropriate order.

In the business and commercial sector, the use of hypermedia is seen to be increasing in such diverse applications as repair manuals, dictionaries and reference books; auditing; trade shows; product catalogues and advertising. All of these developments share a common goal in that the traditional documents in their literal forms are replaced by a more vivid presentation coupled to easier access to stored information. The general hope is to enable the user to carry out data searching more effectively or to convey the specific selling point in a dynamic manner. The success of hypermedia application in this field is also attributed to the use of images and sound. The multimedia features may in some cases conflict with the generic functions of hypermedia in that the attractiveness of moving images and sound can be easily misunderstood to be the essence of hypermedia. It has been suggested that hypermedia is only a subset of the more general class of interactive multimedia [Woodhead, N., 1991], Figure 12. "*Multimedia- the combination of text, graphics, and audio elements into a single collection or presentation- becomes interactive multimedia when you give the user some control over what information is viewed and when it is viewed. Interactive multimedia becomes hypermedia when its designer provides a structure of linked elements through which a user can navigate and interact.*" [Vaughan, T., 1998a].

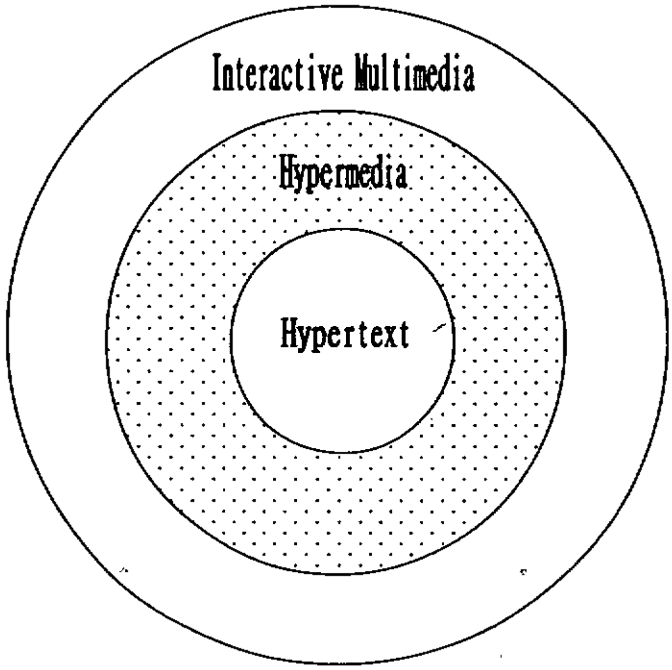


Figure 12. Hypermedia is a subset of interactive multimedia.

3.8 Application of hypermedia for preliminary BSE design

3.8.1 Theoretical framework of LPC Rules model

One aspect of the BSE design process has been examined in previous research work, (see Section 3.7.1.). The objective was to explore the appropriateness and feasibility of using hypermedia for the storage and retrieval of BSE design information especially at the preliminary or conceptual design stage. To illustrate the argument, a HyperCard model was built for the sprinkler layout design problem. The requirements for designing sprinkler installations are stipulated in a set of safety codes, i.e. "Rules for automatic sprinkler installations" which is the combination of the British Standard BS 5306: Part 2: 1990 and the Technical Bulletins issued by the Loss Prevention Council (LPC) of the U.K. [Loss Prevention Council 1990]. These rules are abbreviated as LPC Rules. Thus the HyperCard model is named 'LPC Rules model'. The research results support the argument based on the findings elaborated below.

The BSE design process is considered to be mainly of a semi-structured nature at the preliminary design stage. The well-documented design rules or codes used in BSE industry do not normally specify or suggest the sequence or order of interrogating these rules or codes. Typically, it is the user's experience that plays the most important role for effective information gathering and retrieval. Traditional BSE design software only provides solutions to problems that are well formulated, and where structured algorithms and/or established mathematical formulae are readily available. Proprietary BSE design software rarely accommodates the conceptual phase of the design process.

Hypermedia is considered to be an appropriate tool for developing conceptual or preliminary BSE design. Hypermedia non-linear links can be readily built between chunks of information, a system that functions competently in a semi-structured database. It is a more effective paradigm for this type of application than conventional software systems such as relational databases, spreadsheets, etc. in that hypermedia facilitates the exploration of ideas and searching for a best-fit example against criteria instead of the selection of all occurrences that exactly match the criteria.

Direct conversion of the design rules into a hypermedia model according to the published sequence taken from the original text form, does not provide adequate clues to ensure that the user retrieves the correct design information. Representation of such rules in a linear order may only be useful to an experienced user. Rearrangement of the design requirements in a non-linear manner helps BSE users at different levels of understanding of the design process. Representation of such non-linear information for interactive interrogation can be readily established in HyperCard.

Navigation aids are necessary to assist the user to locate his position when he is disoriented, a situation which is not uncommon when browsing and navigating a hypermedia model. Different levels of navigation aids are provided in the LPC Rules model, which are considered to be adequate to allow the BSE users to return to various levels of the data structure.

The effectiveness of exploring information is found to hinge on the strategic design of nodes and links. The size of a node, i.e. the amount of information carried on a card (a node in HyperCard), should not exceed that governed by the chunking principle which essentially refers to the short-term memory of human beings. Appropriate facilities also have to be provided to advise the user on how to make a choice from those indicated on a card. These include the intelligent links for cross-referencing and automated criteria checking; alternative paths for users of different levels of understanding and the graphical display and transformation of tables (showing design limits) into a more dynamic format.

The ability of the model to recall choices previously made by the user is enhanced by conceptualizing the structure of the model. Several types of relations between various objects of the model are formalized and classified to provide a theoretical basis for constructing algorithms that recall information retrieved in the earlier part of the navigation.

3.8.2 Extension of LPC Rules model concepts to collaborative design

The success of the LPC Rules model has provided a theoretical basis for tackling construction design tasks that are less well structured. The paradoxical nature of the preliminary BSE design has challenged professionals and academics of the AEC industry to revisit design procedures, which have previously been deemed to be 'well established'. These design rules and codes are comprehensive in breadth and depth. However, every time these standard rules are applied to a particular site, reference to the appropriate clauses in the rule books seldom shows a regular sequence or pattern. There is always a wide gap between the rules and the way these rules are applied. Usually this is an area where an engineer plays a vital role in bridging these gaps. Unfortunately, systems to describe the mechanism adopted by an engineer in accessing these design rules are not well understood. The LPC Rules model is an initial attempt to resolve this situation.

In an actual design environment, a BSE collaborates (by all means) with many professionals. Each professional accesses and interprets his/ her own set of design rules and passes his requirements to others. These in return become another set of design rules (constraints) for his counterparts or project team members. These "personalized rules" are organic in nature, i.e. evolving against changing situations. Notwithstanding, "personalized rules" may be treated as another set of design rules in addition to the standard ones that each member takes account of. Thus, it may be argued that the collaborative design environment is similar to that of the LPC Rules model when viewed from the perspective of a single PT member. In other words, the LPC Rules model has been developed to satisfy a single user configuration. On a closer look at the model, the most significant impact of the assumption in the model is reflected in the techniques regarding the construction of links and nodes of the hypermedia model. The principles for tackling design problems, which have been developed in the LPC Rules model are of fundamental importance. The concept that hypermedia may be suitable for less well structured problems can thus be extended to resolving complex problems which have been identified as a typical scenario in collaborative design tasks.

Following the arguments in the LPC Rules model, the next step is to review the use of state-of-the-art hypermedia in collaborative work.

3.9 Paradigm for collaboration

The term "hypermedia/hypertext" has been referenced in many research literature in various fields ranging from collaborative learning, concurrent engineering to computer supported cooperative work. A hypertext-based discovery learning system has been tested for collaborative learning among a small group of students and demonstrated an average learning gain of some 20% [Anderson, A., et al, 1989]. Concurrent engineering activities in the manufacturing field are improved by introducing a "reusing policy" of the available knowledge and know-how, which is realized by using hypermedia concepts and systems [Biennier, F., et al, 1995]. While these examples are specific in their applications, major applications are seen in open hypermedia systems and computer supported cooperative work, which is not directly related to any particular discipline. There is a clear tendency for the collaborative nature of hypermedia to be exploited more and more in the cooperative working environment.

Hypermedia has been considered as an appropriate medium for representing the content as well as the process of collaboration [Streitz, N. A., 1994]. Since the launching of the first ACM (Association of Computing Machinery) conference on hypertext, Hypertext'87, held in November, 1987 at the University of Carolina, there has been an increasing emphasis on collaborative work, which is reflected in the proliferation of papers in this area in the last two conferences, i.e. Hypertext'97 and Hypertext'99. One of the recent examples of research is that a spatial hypermedia services provided as part of a component-based open hypermedia system [Reinert O., et al, 1999]. On the other hand, the increasing popularity of Internet (the World Wide Web, WWW or the Web) gives rise to a different dimension in the development of hypermedia especially in collaborative work. It is natural to argue that the Web should be an ideal paradigm for collaboration because the Web intrinsically provides connections to users in different places and time. However, the question is whether the Web is a genuine hypermedia system or not.

Arguments between open hypermedia system (OHS) research and World Wide Web research have been presented [Nurnberg, P. J. and Ashman, H., 1999]. The thesis claims that the Web is the biggest and best-ever hypertext system, while the antithesis claims that it hardly warrants being called a hypertext system at all. The conclusion of the study suggests that although both fields use the term "hypermedia" when describing the types of systems they build, they use this term in different ways. It is insufficient to compare the Web with traditional OHS with respect to functionality. On the contrary, comparison should be based on the awareness of location of structure of their respective architecture. Nurnberg has made a proposal to foster more substantial cooperation between these two fields. The study also reveals that the Web approach is weak in collaborative support in comparison with hypermedia systems, i.e., provide much of their advanced authoring and collaborative work features based on top of their more powerful infrastructure.

Notwithstanding the strength of hypermedia systems over the Web, open hypermedia systems designed for cooperative work are still in their infancy as far as support for collaboration is concerned [Reinert O., et al, 1999]. Furthermore, references to hypermedia applications related to collaborative design, especially in a refurbishment project, are not readily available. While the comment made by Streitz is relatively broad in nature, i.e. "*hypermedia is an appropriate tool as well as a medium for collaboration*" [Streitz, N. A., 1994], Dix has been more specific in his observation in that at least one type of the groupware for decision support often has a hypertext-like structure, and may easily be used to support design teams as well as individuals [Dix, A., 1998c]. Therefore, in the absence of strong evidence that either the Web or the more sophisticated open hypermedia system may support the type of collaboration activities identified in this research project, it is arguably reasonable to first build a hypermedia system from the very basic principles of hypermedia. It eliminates any possible dispute over the results of this research project, i.e. that the original proposition of using hypermedia may not be fully justified.

In summary, the collaboration model will be built on the concepts derived from the LPC Rules model in the first place, the very original flavour of hypermedia. The immediate argument is the need to extend these concepts from a single user configuration to a multi-user situation. It gives rise to the question how information flow is to be handled, both conceptually and physically. The preliminary collaboration model is revisited and analyzed again under such insights in the next Chapter.

CHAPTER FOUR

Chapter 4: Development of a collaborative design model

4.1 Classification of types of relations between information objects

Hypermedia itself lacks the intelligence to handle any complicated algorithm that may arise in a design process. Also, it does not have any intrinsic capability to communicate with other computer systems similar to agent-based systems. However, its ability to organize information in a nonlinear manner resembles the way a designer typically posts his ideas as his design evolves. Referring back to the CATWOE model which was suggested subsequent to the SSM analysis, the core purpose (or the transformation process T) of the collaboration is perceived as the acquisition of a design information set that can be readily retrieved. For example, the LPC Rules model is able to recall choices previously made by a user. This feature enhances subsequent modification of the model structure. The idea is to segment the design information into smaller information sets in a dynamic manner, i.e. adaptive to user's input. Thus the required information may be retrieved more readily. The technique is to construct the hypermedia model based on the identification and classification of relations between information objects.

In hypermedia, information may be represented and carried in the form of nodes as well as links between nodes. Nodes and links may be seen as objects that can be created, copied, moved, modified and destroyed. The intention is to delineate and classify the relations that may exist in the information/data generated during the collaboration design process. This relationship may then be ported to the hypermedia environment represented as nodes or links. In the case of the preliminary collaboration model, the three primary information elements form part of the transformation process "T". Apparently there are between these elements and a PT member at least three links which can be seen from the basic information model, Figure 5, if each element and the member are viewed as hypermedia nodes. The "C" and "A" (customer and actor) of the root definition include the BSE, MS, SE and HM, all of whom may be seen as different nodes of the hypermedia model. This is justified on the assumption that all PT members would develop their respective design conforming to the format suggested in the basic information model. That is to say, each member would identify his own set of standard information, would review improvement proposals suggested by other members and would then propose his own set of specific design requirements. When the collaboration activities between all the PT members are taken into account, it can be seen that there exist at least three types of relations between a PT member and the primary information elements, i.e. "identify", "review" and "propose".

These three types of relations can be broadly grouped into two categories in terms of their usage from the perspective of a member. The first two relations typically represent the passive role of the member who is a user of the two information elements. A member would use or "identify" the standard information pertaining to his own discipline in order to study or "review" the improvement proposals passed to him from other members. Basically he would not change the standard information or the improvement proposal originally suggested by other member. The third relation reflects the active role of the member who indeed suggests and "owns" the specific design requirements. If a set of specific design requirements is "owned" by all members, it clearly implies an agreement. Therefore, in hypermedia terms, an agreement between PT members may be defined as a node (specific design requirements) connected to four nodes (the PT members) by four links which are of the same type (propose). The schematic presentation of the above analysis and argument is shown in Figure 13.

The total number of relations shown in Figure 13 is twelve. However, if the PT members as well as the primary information elements are considered as nodes of a hypermedia system irrespective of their characteristics, the total number of relations should be twenty-one. The number is calculated based on the definition that a relation is a link between two nodes, or

No. of links = ${}^{7}C_{2} = (7 \times 6) / 2 = 21$

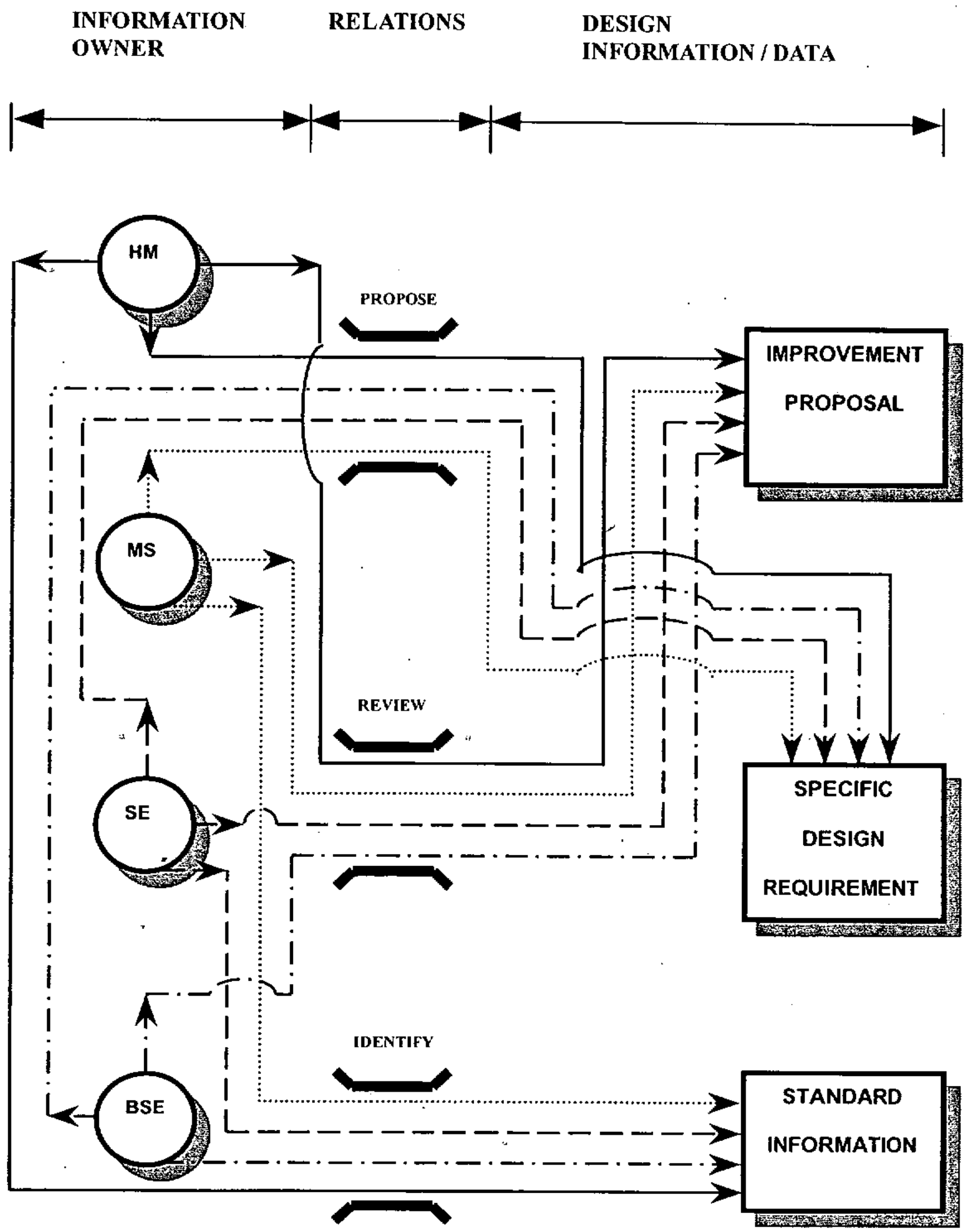


Figure 13. Classification of relations between information objects.

The three types of relations previously defined broadly reflect the connection between two sets of nodes, i.e. the members and the information elements. Nevertheless, links between members are not meaningful if they are not related to design information in the context of a collaborative design process. Also, links between information elements are inactive in the absence of any input from PT members. Therefore, it may be argued that the model shown in Figure 13 essentially represents the relationship that may exist at any given level of abstraction. Clearly this number will multiply when the primary information elements are broken down into smaller components.

The above analysis shows that the information space has been reduced by 3/7 (i.e. [21-12]/21 = 9/21 = 3/7) as a result of classification of relations. It implies that the archiving and retrieval of design information will be more effective because the amount of information to be handled will be relatively small. Notwithstanding, the actual mechanism to facilitate the building up of an agreed design brief has yet to be established.

4.2 Collaborative design vs. information sharing

The model shown in Figure 13 suggests a concept of ownership of an information object. It is this unique relation "propose" or "own" that may bring about the dynamics of the evolution of a design brief. The definition of "agreement" as stipulated in the last section is valid under a simplified situation only, i.e. the specific design requirement only consists of one item of design information. The integrity of an "agreement" is undermined if any sub-item under the specific design requirement is connected with a relation not belonging to the type "propose". Therefore, it may be argued that there is a limitation in applying the 'classification of relations' technique. It is effective in enhancing the recall capability of a hypermedia system in regard to choices made by a user, yet its strength appears to subside when a collaborative environment prevails, particularly in the tracking of an agreement between members. The main reason is that the model constructed under a classification approach lacks the time dimension or the sequence of events, both crucial in the representation of a collaboration process. The time/space matrix shown in Figure 10 is a typical illustration.

Notwithstanding its shortcomings and limitations, Figure 13 does provide the theoretical framework to define an agreement in hypermedia terms, i.e. an information object owned by all PT members implies agreement. The development of a client's brief in its chronological order is diagrammatically represented by the preliminary collaboration model, Figure 9. Clearly the pursuit of an agreement is focused at the node "A" where the entire proposed specific design requirements (subsequently converted to revised improvement proposals) from the respective PT members merge. In other words, only one type of relation would directly give rise to an agreement, i.e. "propose". Node "A" may be represented by a matrix (namely Collaboration Matrix) which coordinates the different design options with the respective information owners or PT members, Figure 14.

	BSE	HM	MS	SE
Design Option 1	Author	Disagreed	Disagreed	Agreed
Design Option 2	Agreed	Author	Disagreed	Disagreed
Design Option 3	Disagreed	Disagreed	Author	Disagreed

Figure 14. Representation of Node "A" by Collaboration Matrix.

In reality, each PT member may present his "Improvement proposals" or "Design options" in a design meeting and exchange them with other members. Essentially they have started a dialog for sharing information. During this exchange of views, each member may be attempting to collaborate with his/her colleagues or merely paying lip service to the process while seeking no agreement at all. In most cases, however, compromise typically leads to at least a partial agreement on improvement proposals. It is unusual for complete agreement to be reached without compromise. However, the machinations whereby change and modifications come about are frequently lost in the exchange of "views". This may be due to the fact that disagreements frequently go undocumented. Concessions may also go unrecorded. Thus valuable information regarding disagreements is lost, with only the final decision/agreement noted. The proposed Collaboration Matrix attempts to overcome these difficulties.

Referring to Figure 14, the BSE has proposed Design Option 1. His action is denoted by a term "Author", which suggests that he is the owner of this particular information object. The views of other members are represented by "Agreed" or "Disagreed", which are positioned at respective co-ordinates of the matrix. Similar arguments apply to other design options. Figure 14 is a snapshot of the collaboration process, which indicates no agreement at this stage. In accordance with the preliminary collaboration model, all the information in the collaboration matrix (Node "A") will be "recycled", which allows PT members to modify the status of the ownership of respective information objects. It should be noted that the term "Agreed" is logically equivalent to "Author", i.e. representation of ownership of an information object. On the other hand, the term "Disagreed" indicates the negative sense of ownership. Indeed the collaboration matrix has suggested a basic framework to document the history of the evolution of a client's brief. However, it fails to cope with the "no agreement" situation when the collaboration matrix undergoes the recycling indefinitely

All references to the application of hypermedia in the earlier analysis of the collaborative design process are fundamentally on a conceptual basis. Inevitably any conceptual model suggested would be subject to different constraints that may hinder the representation of the collaboration of PT members. Given the hypothesis that hypermedia could be an alternative paradigm/ development tool to assist a BSE in handling collaborative design task, a prototype hypermedia model has to be built in order to prove such an argument. Therefore, the next question is how to represent the preliminary collaboration model as well as the collaboration matrix in a hypermedia environment.

4.3 Hypermedia objects

In connection with Figure 13, it is relatively easy to convert the Design Information/Data into hypermedia nodes because these are text and graphics. For example, design information comprises variable data frozen once entered into the system until the next round of updating. On the other hand, the Information Owner is a human being, i.e., capable of cognitive action, represented as an information object in the conceptual models or a node in a hypermedia system as shown in Figure 9 and Figure 13. However, there is an obvious limitation to implementing this concept directly into a hypermedia system. As far as a classic hypermedia system is concerned, a hypermedia node does not "think". In the absence of any additional scripting or artificial intelligence, a node is essentially a dummy or merely a container of static data. By no means can it resemble the behaviour of a human being. There is no common feature between humans and the algorithm for a hypermedia node to simulate a PT member is not available at this stage. Nevertheless, PT members are clearly part of the collaborative design process according to previous arguments. Logically, the conversion of information objects into hypermedia objects has to be examined in order to determine the methodology of how the features of a "human being" may be represented to be commensurate with the complexity of this problem.

With reference to the previous LPC model research, the interface between a user and the hypermedia system is distinct. Clearly the user is "outside" the system which contains all the design information and data. It is homogeneous in the sense that hypermedia objects consist of design data only. In the case of the preliminary collaboration model, evidently a user has been defined as a hypermedia object. Immediately it gives rise to the situation that the boundary between users and a hypermedia system is blurred. It is difficult to discern the complex nature of a hypermedia node that has composite meanings. The hypermedia node that represents a user essentially serves as a pointer to the specific information element pertaining to a particular design option. By no means is this node able to carry any function of a PT member in the strictest sense. Nevertheless, a PT member cannot be anyone "outside" the system according to the SSM analysis root definition. Such a fuzzy situation has to be examined more closely in order to give a precise definition of information objects in hypermedia terminology.

Prior to looking more closely at the model, it may be easier to take a broader view of the problem in order to identify the boundary of the situation. The LPC Rules model demonstrates a typical scenario for a traditional human-computer interface problem. The model and the user of the model are two distinct entities, Figure 15. Although the LPC model allows a user to input data into the system, this must be carried out through the "interface". In other words, the model has been built according to the perception of a BSE who views the preliminary design of a sprinkler layout from a distance through a particular frame of reference or interface. Clearly if the BSE stands inside the model (conceptually at least), he can hardly comprehend the structure of the model.

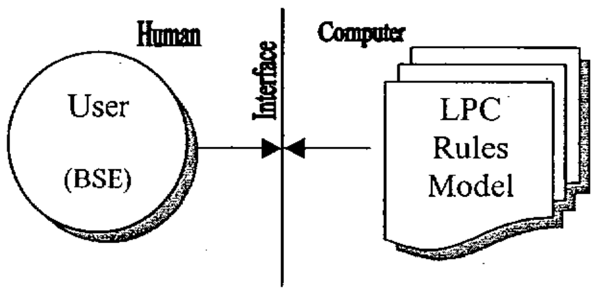


Figure 15. User views computer system through interface.

The preliminary collaboration model clearly suggests that PT members are not segregated from the information elements. They are connected through different types of relations or links (in hypermedia terms). The perceived model is a result of viewing the collaboration process outside a boundary that encompasses both the PT members and the information elements, Figure 16.

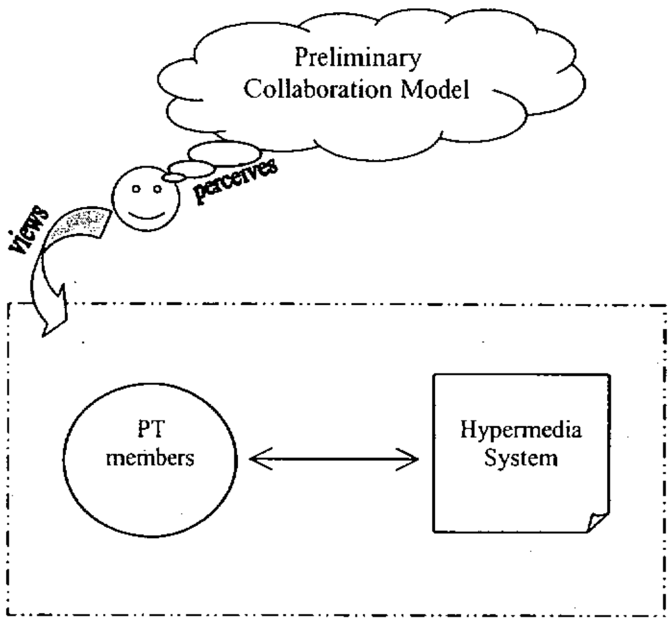


Figure 16. PT members seen as "within" collaboration model.

Hypothetically, it may be assumed that "PT members" of the preliminary collaboration model can fully represent the behaviour of the real PT members. This proposition is true only when the reasoning and the logic of respective PT members can be articulated in explicit rules. This is considered unviable when taking into account uncertainty in the cost of developing such a system argued previously, Section 3.6. On the other hand, this proposition can be proved to be wrong by a simple counter example. If one PT member fails to give a full account of his reasoning and logic of his design task, the "PT members" cannot be adequately emulated in the model. Anecdotal evidence suggests that even a PT member himself may not be able to predict the next move. Therefore, it may be misleading to denote a hypermedia node by the term "BSE" in a collaboration model. The "BSE" node could only at most represent the image of a real BSE, i.e. the snapshot of the output of his design activities. A model may be seen as a series of photographs taken when PT members collaborate.

In fact, it has been suggested that a high level or meaningful representation of the real world objects that define the problem system, is the prerequisite for a collaborative problem-solving environment. Such a representation forms the basis of the interaction between the users and the system [Pohl, J., 1997]. Typically a design proposal to provide central air-conditioning to an existing shopping centre is not good enough for other PT members to assess its viability unless the size of the new chiller plant as well as its location are indicated. In other words, an information item has to be made meaningful to all users through proper association with other relevant information. What is the most meaningful or highest level of representation that may be possibly achieved in respect of "PT members"? Clearly this question has to be answered in the context of the constraints arising from the hypermedia approach. The greatest strength of hypermedia is its ability to connect chunks of information in a non-linear pattern. If each hypermedia node is seen as a container of the information/data that depicts any design contribution or relevant caliber of a PT member, the way to connect these containers would become the most critical task in the construction of the collaboration model. Arising from it, the way in which such information/data produced by a PT member may be captured is another essential feature to be introduced in the proposed model.

When the constraint that a hypermedia node cannot directly emulate a "PT member" is taken into consideration, the collaboration matrix in Figure 14 gives the most concrete representation of the design activities in comparison with other models that have been suggested. The attempt to designate a PT member by a single node has to be abandoned. The fact that a hypermedia node is able to carry many chunks of information has provided the flexibility necessary for further development work through a matrix approach. Therefore, the collaboration matrix may be represented by a single hypermedia node in the most extreme case. However, in practical terms, information contained in the matrix would be distributed to many connected nodes. This is to take into account the limitation of the short term memory of man. As a result, the contemplated collaborative design model would be a network of collaboration matrices (plural) that embody different items of the design brief. Also, it reflects the existence of PT members by showing the decisions made by them, Figure 17.

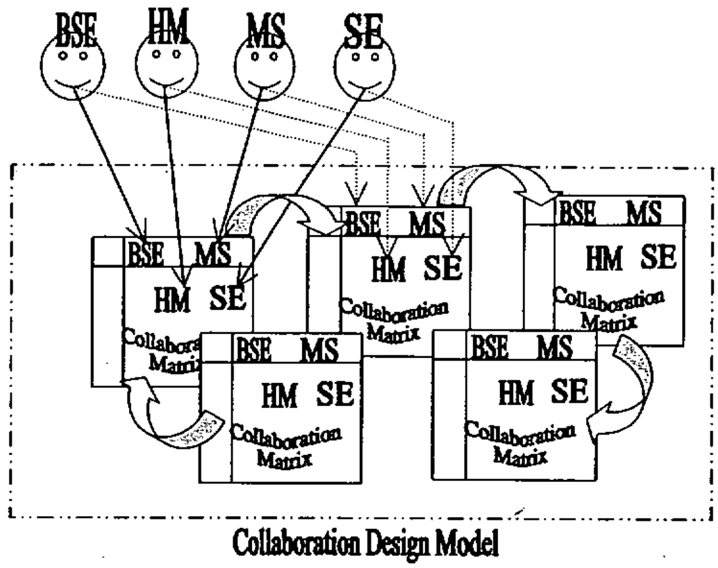


Figure 17. A perspective of Collaboration Design Model based on matrix approach.

So far the defining of hypermedia objects has mainly focused on the representation of "PT members". Pursuant to the cognition that the collaboration matrix is to be the building block of the collaborative design model, previous arguments based on the basic information model and subsequent classification of relations between information elements have to be modified accordingly. How much information is to be carried by a collaboration matrix? In a real situation, "specific design requirements" - the pivotal primary information element in respect of the pursuit of an agreement - consists of a huge amount of design information. As this is a variable data set, the mechanism that is accountable for the chopping of the entire design database into chunks of design information has to be flexible and dynamic. Furthermore, the connection between these matrices should also behave in a very flexible manner in order to cope with the evolution of the variable data set. Morreover, there are many other crucial factors to be examined in order to provide a robust theoretical basis for the construction of the collaborative design model in hypermedia environment (Collaborative Design Hypermedia Model, the CDHM).

4.4 Design consideration and criteria of collaborative design hypermedia model (CDHM)

4.4.1 Author/ reader relationship

The analysis conducted previously focuses on the "propose" relation that is critical in the representation of an agreement between PT members. The "propose" relation connects the core design information, or the variable data set, with the members. Also, the most prominent attribute of hypermedia has been examined, i.e. the ability to connect information objects in a non-linear manner. However, there is another crucial characteristic of hypermedia which has a significant impact on the construction of a hypermedia model, i.e., the overlapping roles of a user who may be a reader on the one hand and a writer on the other.

"*Despite important contributions by literary theorists in areas such as reader-response criticism and deconstruction, the roles of reader and writer have been construed as largely separate. Hypertext, by contrast, places reading and writing in a connected and overlapping terrain, thus providing a forum in which reading and writing can be conceived in such a way that these traditionally separate acts begin to partially coalesce.*" [Snyder, I., 1996] Specialized in Language and Literary education, Snyder perceived that the conventional meaning of author and reader has to be redefined in a hypertext environment where readers acquire a new life by going on-line. Hypertext, by virtue of its electronic form, provides the means for non-linear, discontinuous and associative reading, a process like thinking. The non-sequential manner in accessing a hypertext document gives rise to different notions regarding the meaning of authorship. The control over the text as enjoyed by the traditional author in page-bound text is absent in hypertext and therefore the idea of sole authorship no longer exists. The authorial control also diminishes in hypertext since the author cannot fully control either the reader's path through the text or even the contents of the text itself. Thus emphasis shifts from readers indulging in author-worship or author denigration to collaboration between author and reader. Snyder identifies that the "virtual presence" of an author is amplified in hypertext systems in comparison with print technology because the characteristic flexibility of the reader-centred information technology has a much greater presence for writers in the system. The virtual presence of authors promotes the writer-reader collaboration.

The author/ reader relationship is also seen in the collaboration matrix (Figure 14) which has been constructed to mimic the connection between design information and respective PT members. Snyder's idea that writing and reading partially coalesce in hypertext literature was not fully recognised when the collaboration matrix was being considered. Arising from Snyder's findings, it may be possible to develop a stronger theoretical basis for modeling the collaborative design process in the hypermedia paradigm. When collaboration between writer and reader is seen as a natural attribute of the hypermedia system, its implication and application to the CDHM has to be taken into account in further development work.

With reference to the collaboration matrix of Figure 14 again, the BSE is the author of Design Option 1 while the other three PT members are readers who may "Agree" or "Disagree" with the author. As discussed in Section 4.2, the term "Agree" is logically equivalent to "Author" as far as the ownership of an information object is concerned. In other words, besides the BSE, Design Option 1 is also co-authored by the SE (who "Agree"). For those who "Disagree" with him the BSE may author another design option of which the BSE is conversely a reader. Clearly it fulfils the author/ reader relationship advocated by Snyder in her perception of writing in hypermedia. Nevertheless, the scenario described by Snyder may not be identical to that of the CDHM.

In hypertext literature, the changing roles between author and reader may be a matter of a different style of writing, which could be quite liberal, i.e. no systematic procedures to determine how the role-changing may be managed. In the case of CDHM, these roles have to be defined in a systematic manner on the grounds that the CDHM is a guide map for PT members to locate exactly the orientation and the implication (usually in dollar terms) of an item of design information. A piece of English literature can be read in such a manner that a reader may have freedom to interpret it in his/ her own way disregarding other views. Should such a freedom be offered within the CDHM model? Clearly in his role, a PT member with the flexibility to access a design document according to his own choice, will promote creativity by authoring new information. However, the required flexibility has to be governed by an appropriate framework so that the linkage between existing information items or nodes and the newly created ones can be readily tracked. It has been argued that the construction of a hypermedia document is to be carried out with the cognition regarding "The distinction between structuring 'in the large' and authoring 'in the small'" [Streitz, N.A., 1995].

Arising from the identification of author/ reader roles and the emerging concept of "large" and "small", the relative significance of these roles in the "large" and "small" parts of a hypermedia document has to be examined. If "large" is understood as the framework in which a PT member may develop his design and which no one may change, then such a structure has yet to be identified. On the other hand, "small" may be said to be the arena where a PT member carries out his authoring. As such, the collaboration matrix will be the most appropriate place to realize this purpose. Going back to the question of framework or structure, one obvious requirement is that the framework should facilitate a clear demarcation between the two distinct types of design activities, i.e. writing and reading. It would be disastrous if more than one PT member were to write simultaneously on the same node hence a mechanism must be built into the CDHM to guard against such an occurrence. This problem is known as concurrency control. Furthermore, another control mechanism is required to ensure that the entire collaborative design process will not go on indefinitely in case a "no agreement" situation persists.

4.4.2 Concurrency control

In a real world situation, the final result of the collaboration between all PT members is a document that embodies the design brief as far as the pre-construction stage of a project is concerned. Normally this document is consolidated by one of the members, the HM in most cases. He plays the role of the editor who organizes all the correspondence and memos from other members according to respective design topics. Such a manual system has a very clear boundary that demarcates the designated areas where members form their design input in response to other's proposals. In this case little 'interference' occurs. In other words, each member has no difficulty in identifying his role and that of his counterparts, either as author or reader, under a paper system or e-mail messaging system. These two systems share one common feature, i.e. the relation between the two communicating parties is "I – You": "I" as the author sending "You" as the reader a message either in paper form or electronically.

While conventional systems are effective in segregating the roles of author and reader, they fail to provide any practical means to organize the information or to enable tracking. Every time "I" send a new piece of information to "You" (singular or plural), a new information object has been generated, which is by no means connected to any previous or upcoming information objects in a logical manner. The subsequent design brief is fragmented because of these "islands" of object information. When the collaboration paradigm is shifted to hypermedia system, it is possible to maintain the "I – You" relationship by starting a new hypermedia file whenever "I" would send a message to "You". The result is no different from that of conventional systems, i.e. a collection of hypermedia files that are disconnected. Thus, it is logical to propose that the CDHM should be constructed as a single hypermedia model. Under such an arrangement, the need to connect information objects dynamically is met by the natural attributes of hypermedia. Within a hypermedia model, once created all hypermedia objects are connected in one way or another, i.e., connectivity is no longer a problem for subsequent updating of a hypermedia object. What matters is the rationale in creating the connections. In other words, as long as a message is posted to a hypermedia node, it will never be an "Island". However, a problem arises when more than one member would like to post his message to the same node. It warrants the introduction of a concurrency control mechanism that essentially carries out the function of orchestrating the actions of PT members (either as authors or readers of messages), which are posted to a node in such a way that the ownership of a message or design proposal can be readily identified. Therefore, further development of CDHM hinges on the whether a node should be made up of one collaboration matrix or several matrices. This will determine the logic of the concurrency control mechanism.

It has been argued that concurrency control is particularly easy with hypertext because as long as people work on different nodes, there is no conflict [Dix, A., 1998c]. However, if a node contains text fields that can be updated by more than one member, the above agreement becomes invalid. Nevertheless, the strength of hypermedia in respect of concurrency control may be viewed from a different perspective. Many hypermedia systems exhibit modularity functionality, i.e. hypermedia objects such as nodes and links may be created or removed without any significant impact on the structure of the hypermedia model itself. Again it goes back to Streitz's concept of "structuring in the 'large' and authoring in the 'small'" as discussed in Section 4.4.1. However, the argument here is focused on the consequence of Streitz's concept instead of consideration of designing the architecture of a hypermedia model. In other words, any corruption to a hypermedia object arising from confusion regarding the roles of author and reader (the "small") may have minimal effect on a hypermedia model structure (the "large"). Therefore, the positive statement made by Dix in respect to concurrency control may be modified in that the resilience of hypermedia against bad data facilitates concurrent work. This argument has to be examined in greater depth when CDHM is actually built using a specific authoring tool. An authoring tool is understood to be a tool that sews multimedia (hypermedia as well) elements together into a project [Vaughan, T., 1998b]. It is necessary to review the different authoring tools available and justify the choosing of a tool for the development of CDHM. Clearly it also has significant impact to the formulation of the strategy in tackling the "no agreement" situation, which will be discussed in the Section after the next one.

4.4.3 Selection of authoring tools

Tay Vaughan has suggested that authoring tools can be classified into four different groups based on the metaphor used for sequencing or organizing multimedia elements and events [Vaughan, T., 1998c]. These four groups are as follows:

i. card- or page-based tools,
ii. icon-based, event-driven tools
iii. time-based and presentation tools and
iv. object-oriented tools.

These tools produce multimedia and hypermedia models which are conceptually no different from each other, i.e. a set of nodes connected by links. Nevertheless, the variation in the representation of nodes as well as the logic in the construction of links results in a very diverse manifestation of multimedia/ hypermedia features, which meets the requisites of different applications. For example, the object-oriented tools are particularly suitable for games, in which the nodes are defined as "personalities" as well as events and objects encountered in real-life situation. The time-based tool, strictly speaking, cannot be classified as a hypermedia authoring tool in that the navigation aid available to a user is very limited. The sequence of the events has been predetermined, which is at most seen as an interactive multimedia as explained in Figure 12 of Chapter 3. Preliminary appraisal of these two groups of authoring tools suggests that they may not be the best choice for the CDHM. For example, the object-oriented tool is too sophisticated or too "interactive" with regard to the handling of a collaborative design task in which there is no such item as a bouncing object to be simulated. The time-based tool because of its limitation is also not adequate to meet the navigation need required by CDHM.

Icon-based authoring tools normally require the construction of a structure or flowchart of the events, tasks and decisions developed by dragging appropriate icons from a library. Content such as text, graphics, animation, etc. can then be added to each respective icons. The authoring process is thus segregated into two distinct stages, i.e. structure and content. It is necessary to work out the structure at the outset in the authoring of CDHM. However, in subsequent updating and authoring, a user may be easily confused if he has to break down his work into two separate steps.

Card- and page-based authoring tools are relatively simple in contrast with the other three groups. In fact the earliest commercial product for multimedia authoring belongs in this category, i.e. the Macintosh HyperCard. Owing to its plain representation of the metaphor for organizing multimedia elements (navigation by going to a page or a card), the complex activities arising from authoring and reading occurring at the same node may be accommodated in a more flexible manner. Unlike the approach of icon-based tools, a page or a card can be added to a model without defining any rigid structure prior to starting to construct a new hypermedia model. Hence, the building up of the structure is incremental with the proliferation of content. This approach resembles the development of a design project from conceptual stage to detail design where design information is rarely complete at the initial design stage. In addition, the lack of a well-defined sequence of design activities also inhibits the production of a workable multimedia representation. The situation is even more critical in a refurbishment project where the generation and distribution of information is often in a messy condition. The uncertainty in the scope of a project during the feasibility design stage is a typical example of the messy condition.

Notwithstanding that a well-defined structure is not a prerequisite for starting a new page- or card-based hypermedia model, some kind of structure is necessary for composing a new document. This is the norm when writing in a conventional type of media, i.e. the page-bound document. Previous studies indicate that CDHM results in a formal pattern or structures represented by the Preliminary Collaboration Model and the Collaboration Matrix. The question 'is the page- or card-based tool able to cope with these requirements in the most effective manner?' Given the finite number of choices of authoring tools, the page- or card-based tool has been selected as the most appropriate option for developing the CDHM. It is a logical outcome given the limitations of the three groups of authoring tools. These are eliminated since they are over-sophisticated, possess inadequate navigation aid, or they have incompatible author sequencing, etc.

As mentioned previously, HyperCard, a card-based system, was the earliest commercial authoring tool. It is the most widely available programming system and multi-media authoring tool for the Macintosh [Vaughan, T., 1998d]. The LPC Rules model, developed in previous research work, also used HyperCard as a tool. Hence, the development of CDHM would be significantly streamlined by adapting a HyperCard environment where proven arguments and techniques can be applied. The main features and characteristics of HyperCard will be discussed in later sections. Strictly speaking, the choice of an authoring tool may not be a major concern as long as the ideas of CDHM can be demonstrated, i.e. a prototype model should be adequate. Dix and Ramduny suggested that a prototyping tool should provide good appearance and functionality on the one hand and a reasonable production time on the other [Dix, A. and Ramduncy, D., 1995]. It gives rise to the idea of having a rapid prototyping tool. HyperCard has been considered one such tool that may address both criteria, i.e. performance and development time. Furthermore, HyperCard takes an evolutionary path, which echoes the argument that the building up of the structure as well as the content of CDHM is incremental.

4.4.4 Control of "no agreement" situation

The development of a client's brief basically follows the iteration process, shown in the Preliminary Collaboration Model (Figure 9), i.e. the evolution of the design brief is implemented conceptually through looping within the model. Looping will stop only when there is a complete agreement among PT members typically reflected at Node "A" or the respective collaboration matrix. Such a scenario of total agreement is rare in practice. The concurrency control as mentioned in Section 4.4.2 plays a passive role in facilitating the collaboration design process. It helps to deter the occurrence of inconsistent data and information by restricting the access right of PT members, thus ensuring the integrity of CDHM. Nevertheless, such a control mechanism cannot result in any agreement if PT members disagree with each other. However, notwithstanding the diversity in opinions among PT members, looping should not continue indefinitely.

Human-computer partnership

Clearly, no PT member can be controlled by a computer or the CDHM in his decision-making process. From Pohl's perspective, a decision-support system is viewed as a partnership between human and computer-based resources and capabilities [Pohl, J., 1997]. Computer as a partner should be restricted to the monitoring of problem solving activities, the detection of conflicts and the execution, search and planning of sequences. A partner may give advice or serve as a reminder to his counterpart if he takes a passive role in the collaboration. A partner though should not dictate a decision, e.g., where a boss has the final say. On the other hand, the main concern is to enhance the quality of the design information so that a decision may be made more readily. The quality of information hinges on the adequacy of the data as well as its reliability. Both adequacy and reliability are relative within a set timeframe; i.e. their validity may expire as a situation changes. In short, as far as the CDHM is concerned, active control over the "no agreement" situation is weak. However, the algorithm of CDHM may be tasked to provide the best quality information/ data with a view to assisting the decision-making progress as effectively as possible.

Transforming disagreement into design options

In the absence of a complete agreement, it will be necessary to determine how the looping or iteration can be concluded. In a real situation, the conclusion of a client's brief may be achieved by transforming the disagreements into different design options, which may result in a higher project cost. Typically, an option that incurs a higher cost is deleted from the client's brief. However, if a specific option is considered by the client to be essential (despite the higher cost), it may be included. For example, the design team may choose relatively expensive finishes in anticipation of enhanced aesthetics to yield a more attractive shopping centre. The extra cost has to be justified on commercial grounds, i.e., a more pleasing atmosphere will attract additional customers to a shopping centre. Similarly, the client may favour greater expenditure on the false ceiling, lighting fittings, air grilles or diffusers providing, of course, the tender price does not exceed the project budget. In such instances, these can be included in the client's brief as provisional items. That is to say, if the price of the returned tender is lower than that expected, the client may have the option to include the provisional items as long as the project cost is within budget.

The technique of delaying decision making by putting the "disagreed option" as a "provisional item" in the contract may not be applicable to critical items that have a significant impact on the overall design. For example, the decision to provide central air-conditioning is a typical case. A client's brief normally consists of more than a dozen items of work, which cover different aspects of an improvement project. If these items are divided into different groups, the chance of concluding on agreement for a single group is much higher than that of the entire client's brief given the same project cycle time. The next question is how to determine the criteria of subdividing the client's brief into different groups?

There are at least three methods to classify the design information so that they can be put into different groups, i.e. by work discipline, by functionality of systems and by physical locations of buildings. The three work discipline - structural engineering, building works and building services engineering - imply a framework oriented to the design input of respective PT members. Functionality of systems typically follows conventional practice in defining different types of services such as foundation, framing structure, building fabrics, plumbing and drainage, electrical supply system, fire service system, air-conditioning systems, vertical transportation, etc. While each system will normally have its major designer, supporting input from members of other disciplines is inevitable. Finally, classification by physical location of buildings or systems is the simplest one. For example, design information may be grouped according to building levels.

The first method is not compatible with the design activities of collaboration because each member will build his own "castle" where interface with other disciplines may not be easily developed. The other two methods are slightly better in terms of a collaborative design environment in that no matter whether it is a schematic system diagram or a building floor layout plan (comprising other facilities as well), members of different disciplines have to access it to add or retrieve information. However, the prerequisite of both methods is that schematic design of the project has to be made available first. Otherwise it is impossible to delineate the types of systems or the location of a building floor, to which the members are referring. In other words, they do not tally with the sequence of the development of design ideas and proposals, which normally starts with only a simple objective or some very rough design concepts. It suggests that the traditional sequential development of design work may hinder collaborative design activities because of the relatively rigid procedures in the handling of design information. An architect has to prepare a fairly complete layout before a building services engineer will start to plan the services layout. By the time a BSE discovers that the layout proposed by the architect does not meet the building services requirements and therefore asks for amendment to the layout plan, the architect may be reluctant to make any change in order to minimize abortive work. Input from a BSE or other team members normally plays a passive role at an early design stage or in situations where they are traditionally not expected to take a leading role. Clearly the design of a project will be completed more promptly if only one team member, usually the architect, dominates the design procedures. However, for a refurbishment project, design changes can be initiated from members of any discipline at any stage of a design process.

Compatibility between information and information container

The above argument refers to the classification of design information. Further analysis of the problem suggests that it is fundamentally a mismatch between the nature of design information and the format of the container that is chosen to carry and represent the information. Design intents or options are conceptual and qualitative, which is the most common type of information or data to be managed at the preliminary design stage. By virtue of the qualitative nature of this information, representation of such intelligence on a typical design drawing rarely elicits meaningful comprehension by other PT members. For example, the design intent is "Provide central air-conditioning to a shopping centre that is to be refurbished". However, no one can tell exactly which part of the shopping centre is to be provided with central air-conditioning at this moment because in the early stage of the design process, the new layout plan is not yet available. In contrast, once the layout plan has been proposed, the design intent can be modified as "Provide central air-conditioning to the shaded area as shown on the drawing". At the conceptual design stage when a layout plan does not exist, PT members may be asked to develop their design based on hypothetical plans that usually become obsolete in the later stages of the design process. It can be seen that the matching of the format of information containers with the information being handled is dependent on the level of design activities. Typically a text-based information container (requiring less data structure) would be more effective at the conceptual design stage when drawings (with sophisticated data structure) are more appropriately used as containers for detail design information. An information item at high-level abstraction is more conceptual in comparison with a low-level one. It is therefore suggested that high-level information items are mainly text-based. A survey was conducted to verify this argument by checking the document records of three shopping centre improvement projects and the results of the survey are shown in Appendix 1.

The survey covers the period from the inception design stage, through preliminary design to detail design prior to the letting out of the contract for tendering (bidding). The period is about two to three years. The types of documents reviewed included memos, committee papers, correspondence, etc. The size of a document was neglected in order to simplify the analysis, i.e. each document is counted as one "lot". For instance, a memo of just one page is counted as one lot while a committee paper of ten pages is also counted as one lot. The survey, highlighted in Figure 18, indicates that between 68% and 84% of all design information transferred between PT members was text based.

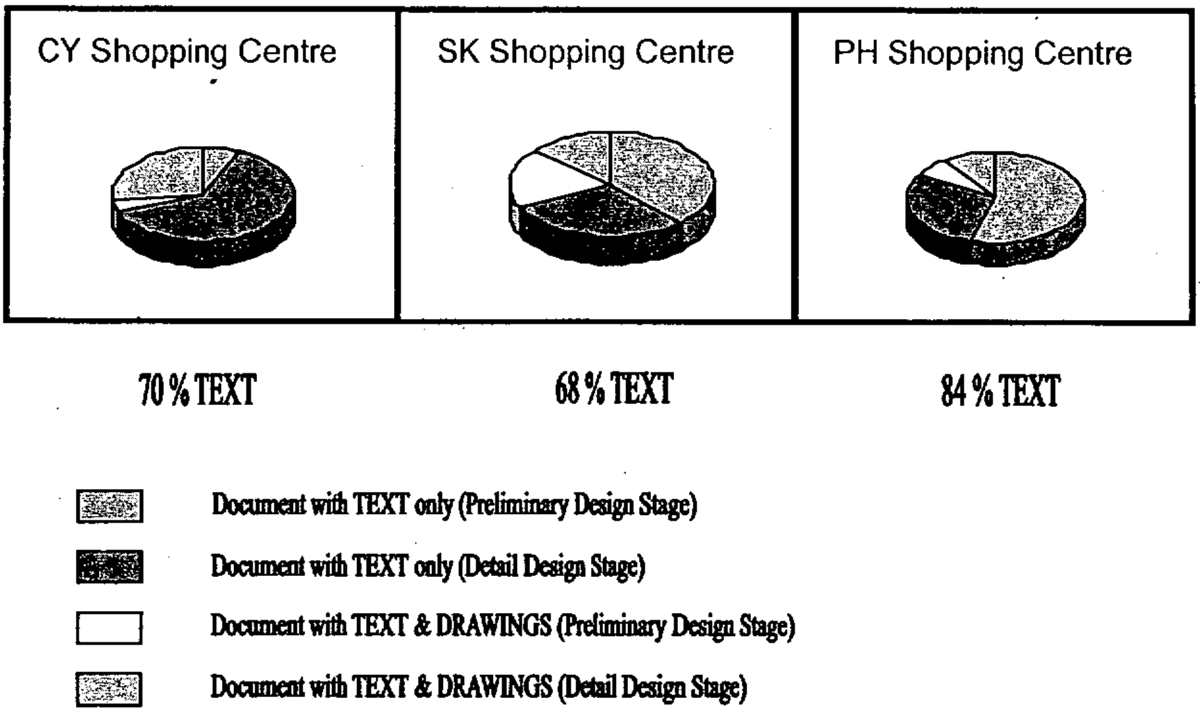


Figure 18. Text-based documents prevail.

Notwithstanding, the application of graphics such as simple sketches in the representation of design options is indispensable. However, text will still be the basic media in the representation of design intent as shown from the survey results while graphics or drawings are adopted for illustration purposes. In this respect, hypermedia indeed meets the requirements that text information is organized to reflect the design brief on the one hand and graphic presentations seen as references connected in a user-definable manner on the other.

Consequently, it gives rise to the idea that the methodology of breaking down the client's brief into different groups may follow the pattern typically displayed by the evolution of a design, i.e. classification of information items according to their level of abstraction in representing a design option. It is argued that any dispute between PT members would be minimized by determining the location of an information item in respect to its level. This should be defined as closely as possible to the common understanding or common practice of the PT members. In other words, it is essential to map out the "natural" mode in which members behave in developing design schemes. (This argument is further examined with a real life project studied in a subsequent section.) Meanwhile, the "mismatch" scenario in the handling of design information is shown in Figure 19.

Building systems and facilities (such as structural frames, electrical systems etc.) are highly defined entities as far as the representation of their content is concerned. The so-called "information containers" of these entities (detail drawings usually) are simply not yet ready at the early design stage in a format that the design information (intents and options) can be slotted into them comfortably. Alternatively, it may be argued that the distribution of the information may be carried out arbitrarily on the assumption that the amount of information handled is not too excessive at the preliminary design stage. Such an argument is valid when it refers to a single project only. However, when the number of projects increases, the result will be chaotic.

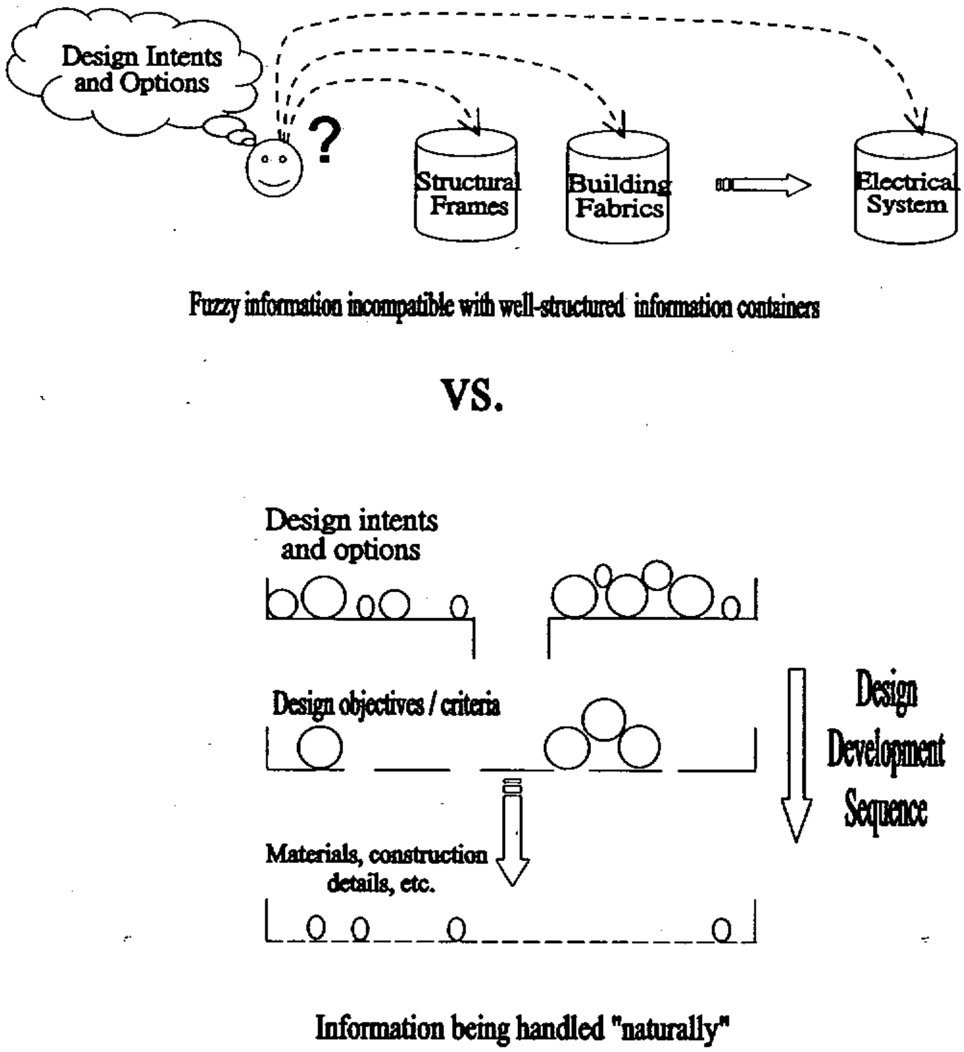


Figure 19. Comparison of "mismatch" and "natural" modes of information distribution.

Design level

Referring to the "natural" mode, the metaphor of 'sand filtering' is applied, i.e., design intent and options are mimicked as sand particles of different sizes. These are filtered by sieves of varying mesh size configured in a descending order. Each sieve represents a particular level of abstraction. In the upper layers, particles of a larger size are captured, which naturally reflect the early design stage. Design information that has broader meaning with significant impact on the overall design is grouped at these layers. Project objectives are typical examples. Following the same principle, design information is grouped with respect to the level of abstraction (design level). In this metaphor, the driving force that pushes the sand particles through the sieves is gravity, which is certainly not applicable to the CDHM. It is also difficult to model a conceptual "size" of an information item. These information items are the results of human creativity, which a computer can hardly predict. However, if the definition of design levels appeals to the experience as well as "common sense" of the PT members, the distribution of the information item may become a "natural" task.

In summary, the control of the "no agreement" situation for CDHM will be accomplished by sub-dividing the design items of the client's brief into smaller groups that correspond to the different levels of abstraction typically seen in the sequential development of a refurbishment project. The use of the term "control" may not be totally appropriate in that there exist no active measures to force an agreement. The grouping of information indeed fosters a passive approach in which the probability of securing a consensus about a specific design option is enhanced by constructing a more meaningful representation of the data structure. The meaningfulness is realized by the "natural" definition of design levels as well as the representation of these levels by a compatible container, i.e. hypermedia. Such a meaningful representation, as advocated by Pohl [Pohl, J., 2000], is one of the prerequisite to facilitate the collaborative design activities.

4.4.5 Design changes

It has been argued that design changes for refurbishment projects occur in an unpredictable manner. Changes may take place at any time from the preliminary design stage to the final completion of a project. However, the impact of design changes on a project in terms of cost and time varies considerably at different phases of a project. For example, changes made at the conceptual design phase rarely have any major influence on the overall cost of a project. On the other hand, design changes that occur towards the end of a project are typically much more expensive. In order to categorize the magnitude of the cost impact, three major stages have been established, i.e. pre-tender (bid) stage, tendering (bidding) stage and construction stage. Design changes taking place during the pre-tender stage will not incur a significant time penalty nor will there be a cost burden except when additional work is planned. Similarly at the tender stage unless the scope of work changes. When this occurs re-tendering normally becomes unavoidable. Changes that happen during the construction stage are most unfavourable in terms of time and cost control. Unfortunately design changes do occur during this stage creating critical challenges to the project team. Obviously the project team has to cope with these changes, resolving any time and/or cost implications. Where budget and time constraints exceed acceptable levels (governed by the client's demands) the project team is obliged to go back to the client for clarification and to resolve these difficulties.

Notwithstanding the time and cost constraints, the most crucial consideration in managing design changes is to ensure that there is no trespassing on the three-tier hierarchy in respect of the authorization of the client's brief, i.e. case conference, Shopping Centre Improvement Committee (SCIC) and Commercial Properties Committee (CPC) (Section 2.2.2). The conclusion of a case conference is essentially reflected in CDHM as both of them are represented by the same group of people, the PT members. On the other hand, the SCIC and CPC are beyond the scope of the collaboration activities pertaining to CDHM. The request for design changes would not normally be raised by SCIC and CPC once the client's brief has been duly authorized. Therefore, the CDHM that represents the client's brief, accepted by the three-tier system, forms the basis for managing design changes during tender and construction stages. Arguably, the procedures and algorithm of resolving the request for design changes are similar to those adopted at the pre-tender stage in respect of resolving disagreement between PT members. In other words, a suggestion for design change may be checked against its respective level of design activities of CDHM and should be associated at one level either positively or negatively with at least one item within CDHM. If there is not any association in one way or another, evidently the PT team has no jurisdiction to entertain such a request.

It should be noted that the CDHM is not confined to the agreed items only and is open to accommodate various design options other than those already accepted by all members. Typically the unresolved items may be categorized as provisional items in a contract, which has been mentioned in Section 4.4.4. Checking of a proposed design change may be carried out against the agreed items as well as those unresolved items. The main purpose of the checking is to search for any connection between the proposed change and information held by CDHM in order to ensure the legitimacy of subsequent design variation.

Pursuant to the analysis of various features relevant to the behaviour of hypermedia in collaborative design situation (i.e. author/ reader relationship, authoring tools, concurrency control and managing "no agreement situations", design changes, etc.), a collaboration matrix, which is seen as the basic building block of CDHM, can accordingly be constructed in a hypermedia environment.

4.4.6 HyperCard

HyperCard has been chosen as the programming tool for the development of CDHM. A brief description about HyperCard including history, architecture and functioning is given in this section in order to provide background on how the model is constructed. There is plenty of documentation available in relation to HyperCard as a software package itself and there is no intention to repeat that here. However, the main purpose of this section is to explain the major features of HyperCard, which play an essential role in the modeling process.

The beginning of HyperCard

Bill Atkinson was the designer of HyperCard. It was introduced in 1987 and was bundled free with every Macintosh sold by Apple Computers. This was the major factor that accounted for HyperCard's popularity soon after it was announced. Atkinson originally built HyperCard as a graphic programming environment and many of the applications built into HyperCard actually have nothing to do with hypermedia. Nevertheless, HyperCard was probably the most famous hypermedia product in the world in late 80's [Nielsen, J., 1995].

The relatively high productivity gain in using HyperCard for building applications may be attributed to the inclusion of a general programming language called HyperTalk that is easy to learn. In particular, HyperTalk is powerful with respect to prototyping a graphic user interface, (GUI), e.g., the programming scripts can be embedded as graphic objects onto which the user may click to perform a certain specified function. These act as the connecting point of hypermedia, linking to the respective information downstream of the navigation path. This is similar to, although not identical with, object-oriented programming that is considered to be more productive than the traditional structured programming. In other words, HyperCard is an authoring system to allow people to get things done a lot faster than programmers using C, Pascal or BASIC because authors use "high-level" tools

[Aker, S. Z., 1998]. In comparison with other authoring tools, HyperCard has poor colour support and lacks vector graphics. Nevertheless, this is by no means a critical requirement for CDHM considering its productivity and flexibility in organizing various design options.

The basic node object in HyperCard is the card, and a collection of cards is called a stack. The main HyperCard support is its ability to construct buttons on the screen and to associate a HyperTalk program with them. Buttons are normally activated when the user clicks on them, but one of the flexible aspects of HyperCard is that it also allows actions to be taken in the case of other events, e.g., when the cursor enters the rectangular region, or when a card is opened. The main advantage of the HyperCard approach of implementing hypertext jumps (program language statements) is that links do not need to be hardwired, i.e., anything that can be computed may be used as the destination for a link.

Operating principle of HyperCard

HyperCard has been designed to allow different levels of complexity ranging from the most basic browsing operation to authoring and the use of advanced programming, i.e., the user can change his user level to the most appropriate mode of his work. Five levels are defined, namely (i) browsing, (ii) typing, (iii) painting, (iv) authoring and (v) scripting. The user chooses his required level at the "Preference card" in the "Home stack", Figure 20. Each level adds power to the abilities of the previous level. With browsing, the starting level, the user can find information with no text entry or editing. Typing and painting are conceptually similar levels that allow a user to change the displayed information but without changing any navigation path. By setting the level to authoring, the user can modify the layout of buttons and fields, which may alter the linkage between nodes and consequently the navigation path. Scripting is the highest level that permits the user to carry out modifications, including programming using HyperTalk.

Notwithstanding the configuration of five preference levels for access to various HyperCard capabilities, these can be generalized into three different environments: browsing, authoring and scripting. Throughout the entire process of building the CDHM, the scripting level has been used.

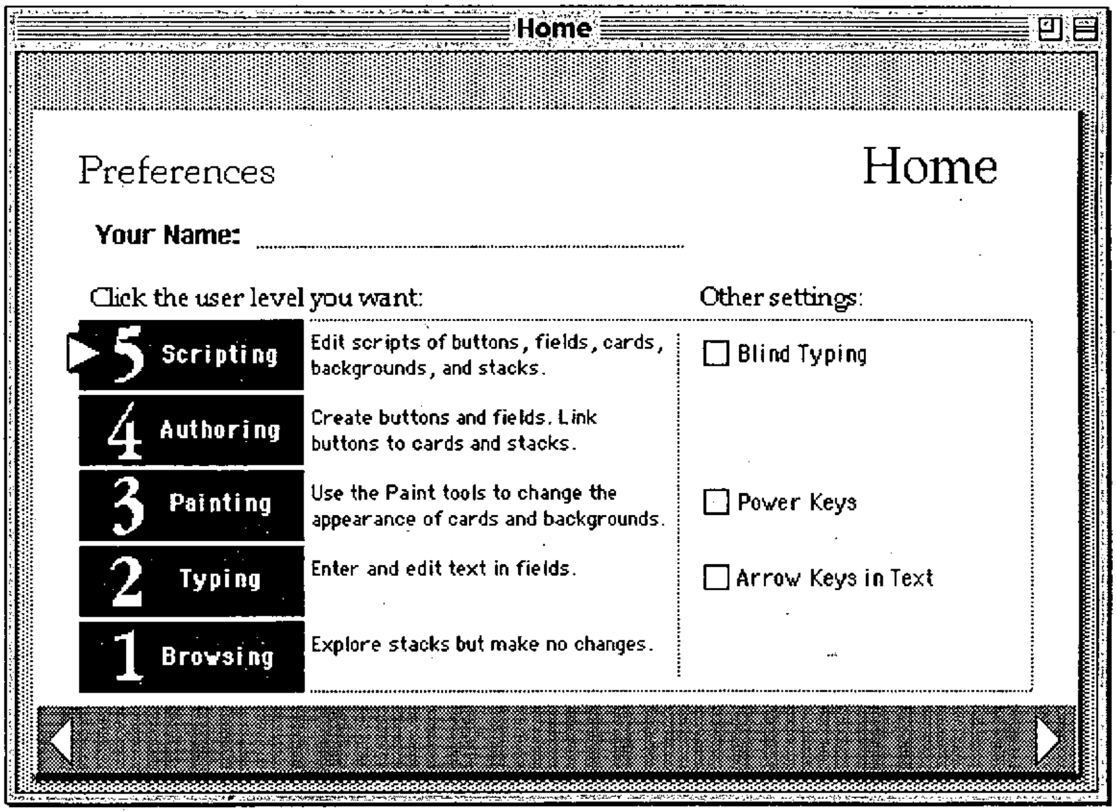


Figure 20. The Preference Card in Home Stack for setting user's level.

The basic elements of browsing

In the browsing environment, the user level displayed on the Preference card has to be set at Browsing or Typing. The basic elements of HyperCard in the browsing environment can be classified into three categories according to their functions:

(i) basic building blocks for HyperCard applications,

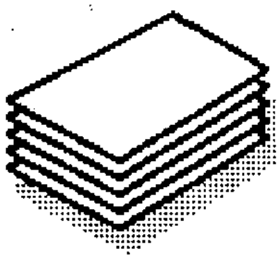
(ii) navigation aids to assist the user to find his way when he is disoriented and

(iii) medium for communication between the user and HyperCard.

Basic building blocks

For any HyperCard application, there are five items used as the basic building blocks: stacks, backgrounds, cards, fields and buttons.

Each stack in HyperCard is a separate Macintosh disk file, which is shown as a HyperCard document icon in Finder, Figure 21. A stack can be opened by double clicking the stack icon to start a HyperCard program, i.e., browsing cards according to various navigation paths as built. There is no restriction on the type of information stored in each stack, i.e., they may be dissimilar in nature. In addition, information relating to different data can be linked even if there is no direct relation between them. The stack designer is free to choose anything to be put in a stack, e.g., text, graphics, sounds, movies, etc. On the other hand, he needs to determine whether he should put everything into one stack or several stacks, as the hypermedia link provided in HyperCard can be extended across stacks. (There is no apparent difference as far as the screen display is concerned.) However, some HyperCard functions only work within the current active stack such as the "find" menu and additional scripting may be required to carry out the same action in other inactive stacks. Hence browsing time may become longer when using several stacks. This was one of the major considerations in deciding the architecture of CDHM. Ultimately the model was built in one single stack in order to maintain effective connectivity between various design options that undergo a gradual evolution process as a result of collaboration.



HYPERCARD STACK

Figure 21. The Icon of a HyperCard Stack as shown in a folder.

Every card is made up of two layers, background and foreground. Whenever a new stack is created the user must assign a background to it which is the background layer to be adopted for the first card of the new stack. This chosen background will become the default background for the other cards to be created within the same stack. While every HyperCard stack has at least one background, even if it is blank, a stack can accommodate cards with different backgrounds. Cards sharing the same background cannot have their background modified individually, i.e., any change to a card background will have a global effect for other cards of the same stack. Logically it is not advisable to place any information on the background layer if it is to be modified on an individual card basis. For instance, it is possible for HyperCard to disable a button temporarily. If the choice of a user is to be restricted pertaining to certain criteria, it is natural to place the button that provides such choices in the foreground. This technique is used in the design of the Collaboration Matrix regarding concurrency control.

A HyperCard card is the major element for carrying and displaying information, i.e., it acts as an interface between the user and HyperCard. Text, graphics, buttons and fields cannot be shown anywhere but on the card. Only one card is allowed to be called at a time, which has a pivotal effect in deciding the data structure of the CDHM. For example, since the Collaboration Matrix cannot be represented by a single card, it must be chopped into smaller chunks in order for each chunk to fit within the boundary of a card. This in turn affects the design of the hypermedia links between the cards. Each card thus serves the purpose of being a node in the hypermedia network and sets the limit of the amount of data that may be shown on the screen.

HyperCard fields normally use an object attached to a card to carry textual information, including numerals, although it is not absolutely necessary for a card to carry a field in order to have text displayed. Text contained in a field may be "true text" which can be searched while the user may also create "paint text" using the paint tool. Paint text is essentially bit-mapped graphics, which cannot be edited like traditional text nor can it be 'searched'. A field may also be used by the author to place and convey any message or, alternatively, it may be used as the medium for the input and output for applications in computational hypermedia. A HyperCard field is very flexible in that there is no need to define the number of characters in that field before its creation and the size and style of the fonts can be varied as and when required. Also there is no restriction with regard to where to locate a field. In principle, a card may carry an unlimited number of fields. Furthermore, a field may be used as a button to make things happen by locking the text of a field, i.e. the field text cannot be modified when clicked but instead a HyperTalk message is generated. As a field can be placed on the background or the foreground of a card, a user has to be careful in deciding where to place a field. By locking the text of a field, concurrency control may be implemented in CDHM. The locking function is automated in respect of the identification of PT members.

Buttons are primary navigation tools for browsing through a HyperCard stack. A well-designed stack should let the user browse through its information simply by clicking buttons. The essence of hypermedia is implemented by means of buttons in that the user may go to other cards of the same stack or switch over to another stack in a non-sequential manner simply by clicking the required button. A button may therefore be attached to a card. The button icon may appear in a variety of forms. It can also be customized with regard to location, size etc., be made transparent and overlap with other graphics or text. Buttons placed at the background layer will be shown in all cards sharing the same background within a stack and can be clicked on even when a card is shown in its foreground layer. The main feature of HyperCard buttons is that there is only one type of linkage afforded by the basic HyperCard function, i.e., a simple uni-directional and unconditional link between two cards. A direct linkage between a button to a field or another button is not feasible. This has caused some trouble in the development of CDHM where access to a specific field is required in seeking agreement between members. The problem has been resolved by adjusting the data structure and providing special HyperTalk scripts to the buttons.

Authoring

HyperCard gives the user fast access to a variety of information. However, the real power of HyperCard is that it allows the user to establish relationships among collections of information and to dictate what operations are to take place with each navigational step. In order to organize the information in a required manner, it is necessary for the user to gain access to the fundamental building tools, i.e., painting, fields and buttons, which are meant to be the authoring environment of HyperCard. In the authoring environment, the user may modify or create many things including graphics, fields, buttons, backgrounds and stacks. The user level must be set at Painting or Authoring.

The HyperCard menus change when the user switches from the browsing environment to the authoring environment. For example, two more menus, "Tools" and "Objects", appear in the authoring environment. These two menus basically equip the user with the necessary facilities for the manipulation of graphics, buttons, fields, backgrounds and stacks. In carrying out authoring, all these elements can be copied, cut, pasted or duplicated. One of the main differences between them is that only graphics are bit-mapped images while the others are objects. A HyperCard object can be picked up as a whole to move around or it may be selected and placed somewhere else. Bit-mapped images on the other hand cannot be picked up as objects unless they are trapped. As such, designing cards with graphics requires careful planning of the different images because it can be difficult to separate them for any subsequent modification. On the other hand, graphics may overlap with buttons or fields to improve the aesthetic display of a card or even enhance the effectiveness of navigation because the user can comprehend the message conveyed by a card more readily.

The design of buttons may be considered as one of the most crucial authoring activities in the creation of CDHM. How a button looks and what a button links to will affect the effectiveness of navigation and hence the collaboration between PT members. The icon of a button can be only modified by turning on or off the pixels of the icon bit-mapped image. This is not convenient if it is to be compared with the painting facilities provided by the painting tools. Under such considerations, most of the buttons created in CDHM are annotated by their names by choosing "Show Name" from the Button Information dialog box, Figure 22. Alternatively a button can be made transparent and placed on top of certain desired graphics ready to be clicked by the user.

With regard to the building of links, HyperCard has provided a powerful tool for the user to establish an express link from a button to any card or stack just by a few simple steps of clicking a mouse. By choosing the "Link to..." button from the Button Information dialog box, a new window is shown asking the user to indicate his preference by selecting the card or stack currently shown on the screen. In this way the user is allowed to page through cards in different stacks when seeking the target to be linked.

It can be seen that hypermedia links can be readily built in the HyperCard environment in a flexible manner. The real challenge in authoring a HyperCard model for design applications such as the CDHM, is the need to handle a set of arguments that have been or will be put forward by PT members. These arguments represent the variable data set that is defined in the Basic Information Model (Figure 5). In other words, the challenge may be seen in two different ways, i.e. the generation of containers for new arguments and the creation of connections between the containers. This dictates what kind of information should be connected and how to organize such connections.

Scripting

Scripting is the highest user level where the user can access the power to add or change HyperTalk scripts of the HyperCard model as well as other facilities provided in the Browsing and authoring environments. HyperTalk scripts are attached to respective HyperCard objects, i.e., stacks, cards, backgrounds, buttons and fields. Paint graphics are not objects as far as HyperTalk programming is concerned and therefore cannot inherit any HyperTalk scripts. However, when a HyperCard object is copied, all the scripts of the original object will be inherited by the new object. That is to say HyperTalk programming may be carried out on a modular basis, which is much easier for modification and thus a rigid programming plan may not be strictly required prior to building a model.

HyperTalk is built around a system of sending messages to objects. As HyperTalk scripts are attached to a particular object, the underlying purpose of the script is to intercept a HyperCard message for its object. When the script identifies a message addressed to its object and its own script name, it directs HyperCard to follow instructions in the script. A script that reacts to a message is called a "message handler". When the script intercepts a message, it handles the message accordingly. This is illustrated in Figure 23. HyperCard keeps sending an "idle" message when the user is doing nothing to the computer. With a "mouseUp" handler, the button script does not respond to the "mouseDown" message when the mouse is pressed but it is interrupted when the mouse is released; the script command "go to next card" is executed and HyperCard advances to the next card.

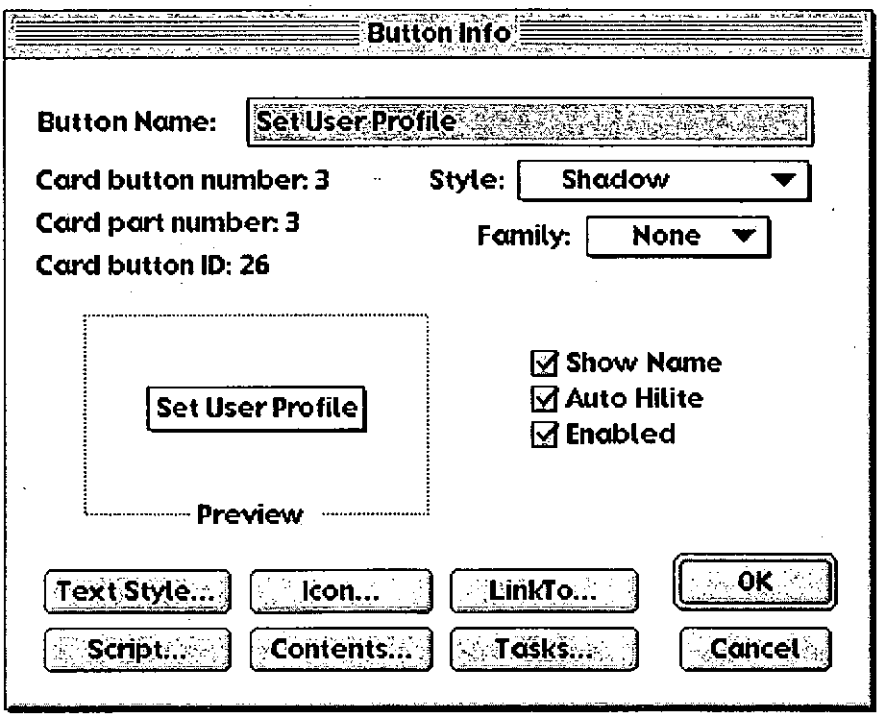
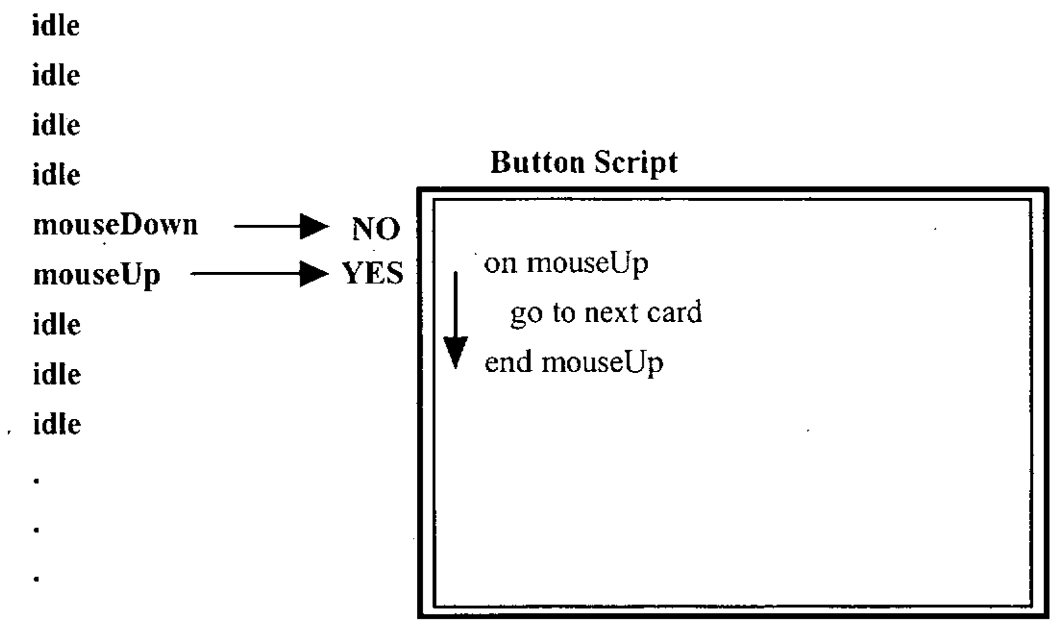


Figure 22. Button Information Box for modifying the function of a button.

HyperTalk can also provide many different facilities to develop various multimedia applications, including sound. For CDHM, HyperTalk has been applied mainly to enhance the effectiveness of a logical interrogation for design information including searching for a particular card to meet preset criteria, computing data, accessing external files and applications, etc. Experience indicates that HyperTalk scripts are essential in providing concurrency control functions, which indirectly facilitate the collaborative design process.



mouseDown message does NOT match with handler--- no response
mouseUp message matches with handler--- button script executed

Figure 23. HyperCard object in action when message matched with a handler.

Navigation aids

With the basic building blocks in place, the CDHM may be constructed in an incremental manner. The less structured architecture of hypermedia provides flexibility for the user on the one hand but it may easily confuse the user. (Sometimes called "lost in hyperspace"!) Such a disorientation is attributed to the lack of directional indication in the HyperCard model, which may not be readily defined by virtue of the complexity of the data being handled. HyperCard offers at least two elements to help the user find his way out, i.e., the "Home stack" and the function "recent" under menu "go".

The Home stack is best described as a kind of master index that a user can create for all the stacks. When the Home stack is opened, the first card shown is called the Home card.

This displays all icons representing each stack to which the user wishes quick access, Figure 24. These icons are buttons, which when clicked, will set in motion the necessary action to open and display the stack that is "linked" to that button. The Home card may be customized by adding more icons for linking to other stacks. However, a stack need not have an icon on the Home card for the user to open that stack. The user can always choose "Open Stack" from the File menu and select the desired stack file from the standard file dialog box. However, the Home card is not used in the architecture of CDHM. As an alternative, several purpose-built cards serve as the menu cards. The main reason is that the CDHM has several levels of menu cards for concurrency control as well as tracking proposals and agreements authored by PT members; consequently going back to the Home card would not be of any assistance to a PT member who has lost his way.

The Home Stack also contains three special cards that help HyperCard find stacks and other files nested in disk folders. These cards are labeled "Search Paths" with separate cards for Stacks, Applications, and Documents respectively, Figure 25. Pathnames shown in these cards guide HyperCard in its search through the disks for stacks or other files. Therefore, the user may list the pathname of the stack to be opened if HyperCard is unable to locate a particular stack. This normally happens when the target stack is not in the same folder as the current stack.

However, HyperCard cannot locate application programs that are placed in other folders, e.g., the Microsoft Word program when accessing an external word file. To establish a new search path the user may alternatively respond to the dialog box with the prompt "Where is" when HyperCard cannot locate a stack, document or application. After the file is selected manually, HyperCard logs the pathname in the appropriate listing. Subsequently, the user never has to consult these pathname cards.

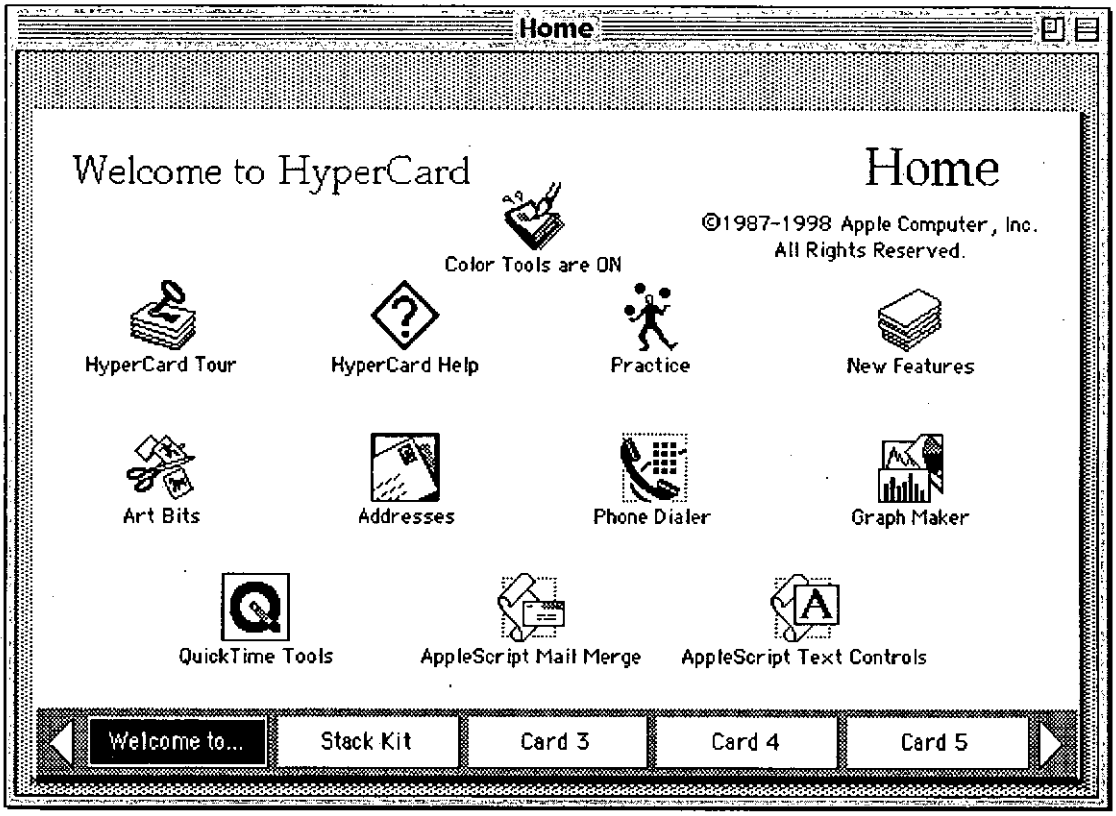


Figure 24. The Home Card.

The HyperCard command "recent" shows the miniature representations of the last forty-two cards that a user viewed on the screen. Clicking any one of these miniatures will result in instant access back to that particular time. It is an important hypermedia feature that represents typical non-sequential browsing. Nevertheless, experience gained during the development of CDHM suggests that "recent" was not as helpful as expected. This may be because the miniatures displayed did not give any clue that tallied with the logic of the CDHM arguments unless the user remembered the unique card he wished to recall. Furthermore, the resolution of the miniatures is not fine enough to distinguish between similar cards, especially where the cards do not have prominent graphics but strings of text. As a consequence the "recent" command was not used.

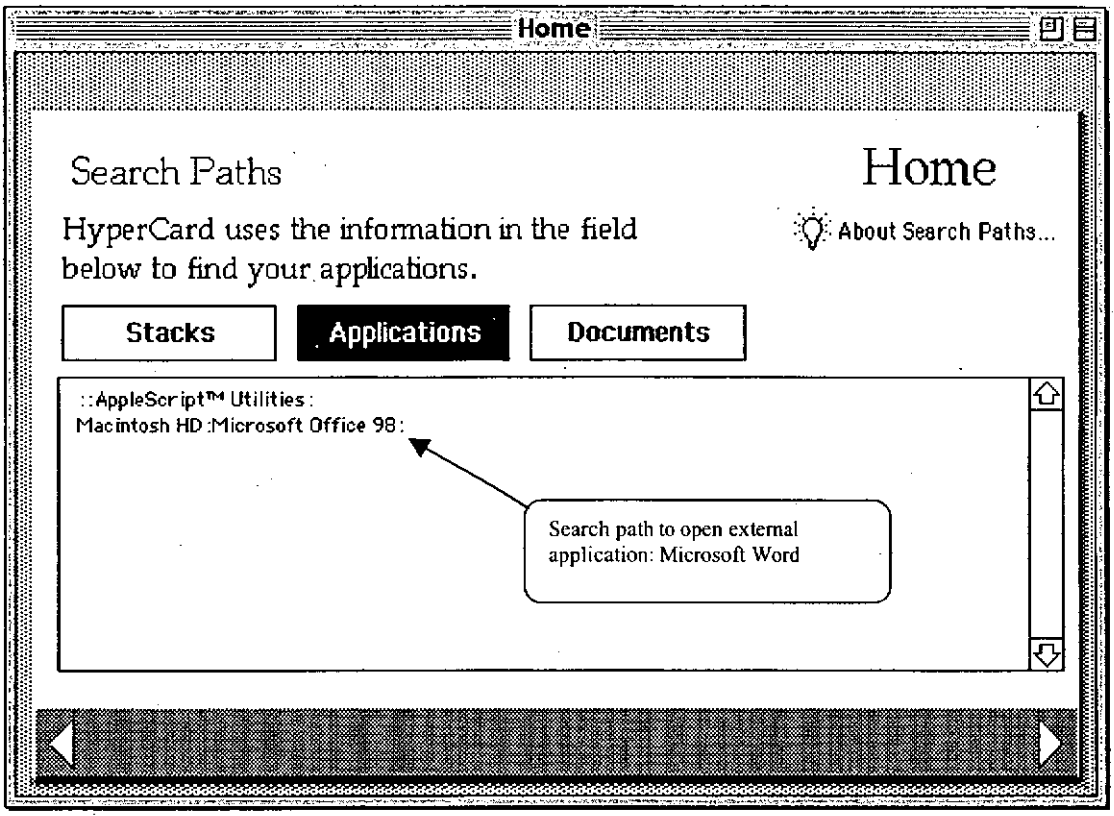


Figure 25. Search Paths cards to record and display pathnames of various files, applications and stacks to be accessed by HyperCard.

Medium for communication between the user and HyperCard

One essential HyperCard element, the Message Box, can be characterized as being the primary communication avenue between the user and HyperCard, or between the user and the HyperCard stack. The Message Box can be made to appear on the screen by choosing Message from the Go menu. It is a special kind of window designed for HyperCard. It has a single line for text display, Figure 26. The user can type commands into the Message Box. Commands are actually words in the HyperCard language vocabulary. For example, with the "Go" command entered in the Message Box, which is the most frequently used HyperTalk command, it is possible to navigate from stack to stack. The Message Box is not used in the CDHM itself because it would require novice users to know some of the

HyperTalk commands, which in turn might affect the effectiveness of navigation. However, it was used during the development process for testing of HyperTalk commands.

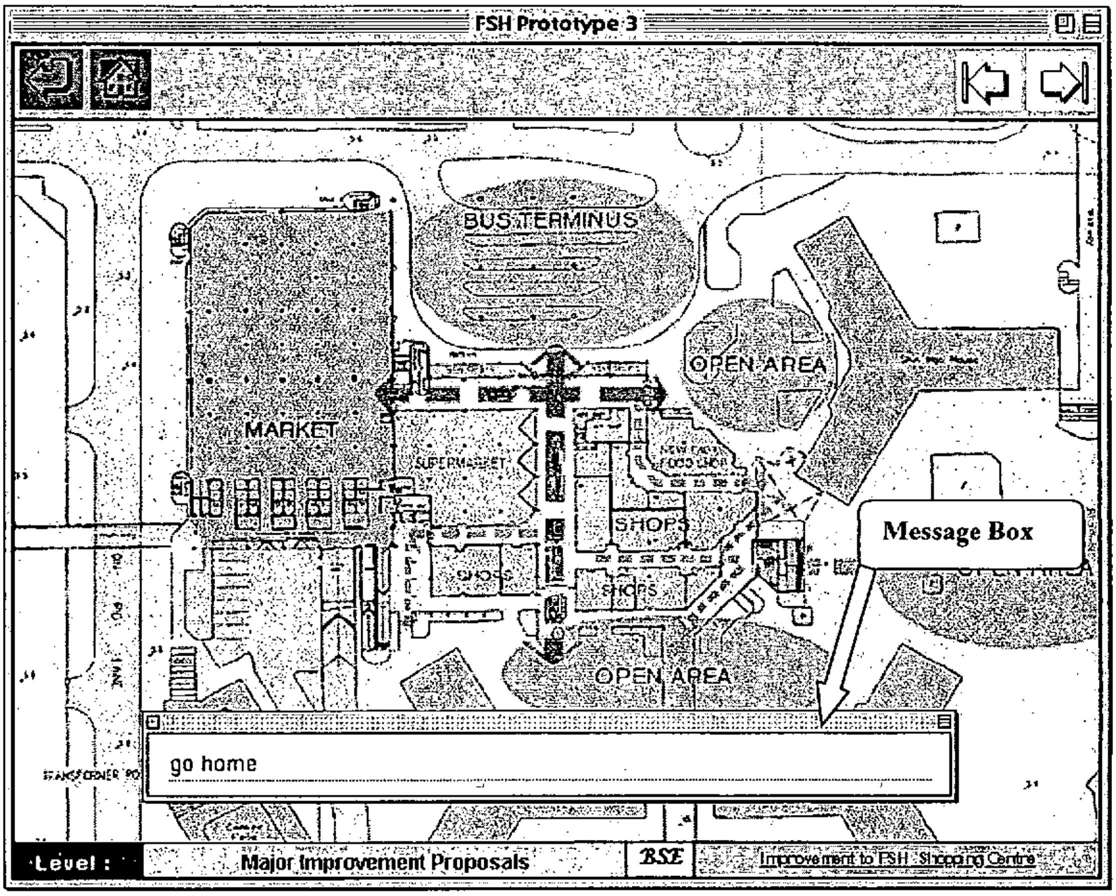


Figure 26. Message Box as alternative means for command input.

4.4.7 Collaboration Matrix

In accordance with the concepts arising from the model described in Figure 14 and 17, the following activities have been identified as the primary functions of a collaboration matrix:

A. identification of PT member,

B. input facilities for design intent and options,

C. representation of choices made by PT members and

D. connection with other related collaboration matrices.

A "card" is the basic hypermedia node of the authoring tool HyperCard. The simplest approach is to put all these functions onto one card. The available tools to realize the requirements are buttons and fields. However, there is no hard and fast rule regarding the criteria of deciding whether a function should be implemented by a button, a field, or both. In principle, all of these four functions may be implemented by providing buttons only. For example, four buttons may be created to represent the four PT members respectively. A user will click "his" own button in order to identify himself. Under such circumstances, a user may carry out his authoring simply by clicking buttons. The only exception is Function B where the input of design intent and options cannot be executed in the absence of fields where the text of design information may reside. Typically it reflects the two different aspects of authoring, i.e. creation of new design ideas as well as construction of linkages between these ideas.

Prior to the construction of any buttons or fields, it is necessary to determine their locations on a card that is a part of CDHM. Strictly speaking, buttons and fields can be placed anywhere on a card without incurring a significant impact on the representation of knowledge and subsequent navigation, provided they tally with the graphics shown on a card. Notwithstanding, the difference between button and field in respect to their characteristics in handling data, does impose constraints on the modelling task. For example, a button can only accommodate fixed data while a field can handle both fixed and variable data. Also, the HyperCard button has been specially designed to create links between cards by just a few mouse clicks. Therefore, as the first approximation, buttons and fields are assigned against respective Functions as follows, Figure 27:

Primary Functions	Button	Field
A (Identity)	✓	
B (Input)		✓
C (Choices)	✓	
D (Connection)	✓	

Figure 27. Mapping Button/Field vs. Primary Functions.

These primary functions form the basis on which several essential tasks of CDHM may be realized, i.e. (a) concurrency control, (b) control of "no agreement" situation and (c) managing design changes. These tasks are meaningful in comparison with the primary functions as far as the collaborative design process is concerned. It agrees with Pohl's argument that a meaningful or high level representation of the real world object is the prerequisite for a collaborative problem-solving environment. Again, in theory all the required buttons and fields may be placed on one card in respect of the representation of the three tasks. Nevertheless, such a card will obviously be "overcrowded" with information. Therefore, the CDHM is represented as a series of HyperCard cards in order to acquire a "meaningful" manifestation of the collaboration process.

A stack is a collection of cards. As HyperCard cards may be connected non-linearly, the sequence and relative position of the cards is immaterial. In other words, the flexibility of HyperCard allows the development of CDHM to be carried out in the absence of any prior rigid framework for a stack. However, the absence of a rational organization of a stack would imply that a systematic approach in maintaining CDHM is lacking. In fact, three different types of stack structures have been suggested by Stephen Wilson [Wilson, S., 1991], i.e. Sequential, Index, and Branching Stack Structures (Figure 28).

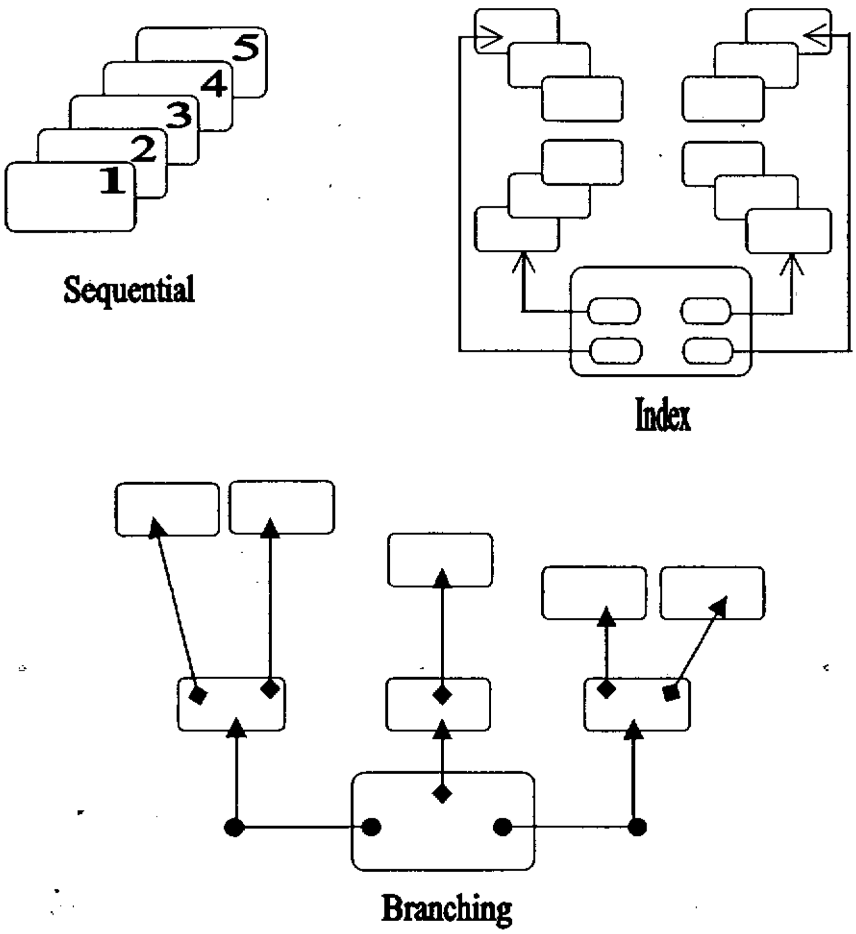


Figure 28. Sequential, Index, and Branching Stack Structures.

In short, collaboration matrices will be built using the available tools including buttons, fields (containers of information) as well as cards (container of containers) in various stack structures to provide the necessary primary functions. On this basis, the respective tasks of CDHM are to be realized. Subsequently, a collaboration matrix that is essentially a 1-row by 4 –column is constructed to cover the discussion of "Project Objectives", Figure 29.

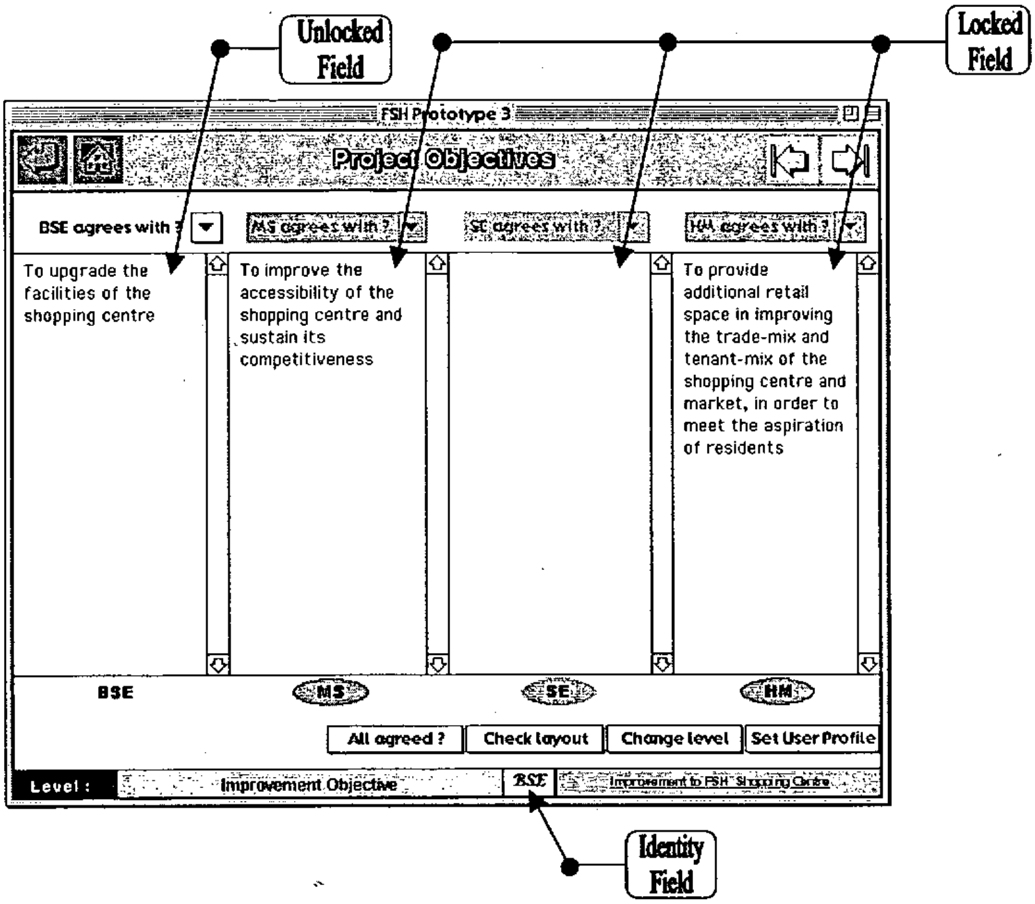


Figure 29. Collaboration Matrix for "Project Objectives".

Concurrency Control

The four columns are fields to hold the design information input by respective PT members, i.e. BSE, MS, SE and HM fields. Under the asynchronous mode of collaboration, each PT member writes in his own field according to his time schedule. Once he has completed his authoring, he "broadcasts" his proposal by sending his file to other members. The incoming file overwrites the one residing in the receiving member's system, which essentially completes the updating process. Therefore, it is a prerequisite condition that the collaboration matrix should be able to prevent a member from writing on an inappropriate field, i.e. concurrency control. This is implemented by locking a field against a respective PT member. In this example, the MS, SE and HM fields are locked while the BSE field is unlocked. Unlocking is achieved by the BSE 'logging-in', which is indicated in one of the lowest fields (the Identity field) displayed on the card as "BSE".

Locking and unlocking is realized by a script attached to the card that holds the collaboration matrix. This script interrogates the 'Identity field' of the four PT members. Only one field, corresponding to the identity of the PT member who has logged in, is unlocked at a time. In this connection, another card is required to provide an interface where a PT member may indicate his identity, Figure. 30. When a user receives a CDHM file from another PT member, he has to log in a correct identity to enable the buttons and fields to work properly. A card button namely "Set User Profile" is provided in most of the cards of CDHM to provide a shortcut to access the interface card. When a user clicks one of the selections (i.e. Building Services Engineer, Maintenance Surveyor, etc.), the corresponding abbreviation of the PT member's identity is put in the Identity field, "BSE" in this case. The 'Identity field' is placed at the background of the card so that it can be shown in all other cards. Every time a card is opened, the Identity field will be interrogated to determine the status of other HyperCard objects in this particular card, i.e. a button is enabled or a field is locked. For simplicity of testing the CDHM prototype, a password, which can be easily built into the model at a later stage, is not necessary for access.

Several buttons and fields are placed in the background. These appear in all cards of CDHM, shown in Figure 31. The main purpose of these HyperCard objects is to provide navigational aids directly or indirectly. These aids include four buttons and three fields:

i. go “back” button to view the card browsed previously,

ii. go “home” button to go to HyperCard Home stack,

iii. go “next card” button according to the sequential order of cards,

iv. go “previous card” according to the sequential order of cards,

v. “Identity Field” to denote the identity of the log-in user,

vi. “Project Name Field” to denote the name of project and

vii. “Design Process Level Field” to denote the current design stage.

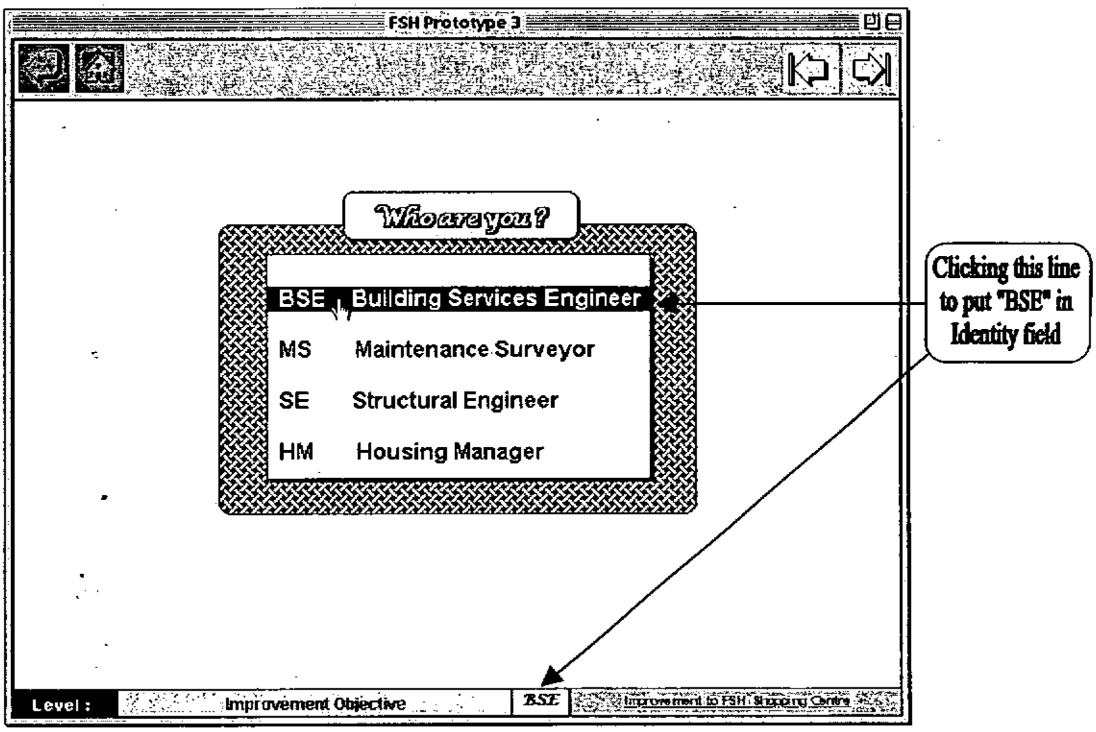


Figure 30. Interface card for user to log in identity.

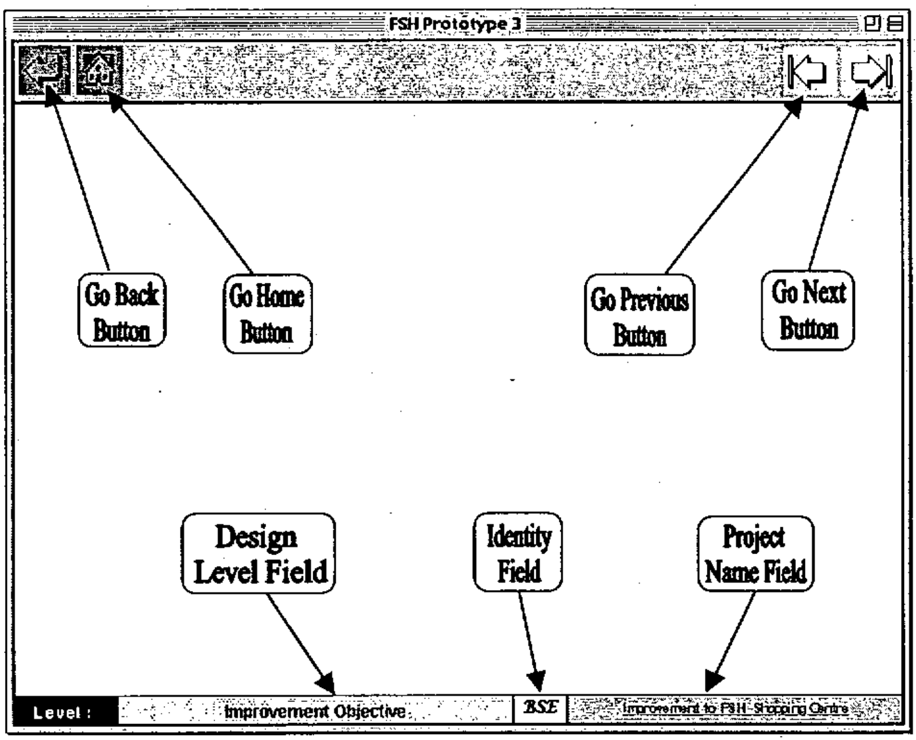


Figure 31. The background with background buttons and background fields.

The four background buttons provide a user direct control for navigation at will. The three background fields serve as landmarks for a user to orientate his location and status within CDHM. The display of these fields will change according to the choices made by a user in respect of several aspects of consideration including which project a PT member is working on, level of design activities and the identity of a user. This information provides a PT member with a signal to help him determine his next step. The Identity field and the Design Level field are also used as input to the script that assists a member to make decision.

As previously mentioned, the Identity field imposes constraints on the activities of a user by disabling buttons and locking fields so as to fulfil the requirements of concurrency control. Referring to the example shown in Figure 29, the four fields are locked in such a way that only one field can be written by one member at a time in order to ensure no loss of information due to deletion by an unauthorized user. (Concurrency control is a measure to rationalize the authoring activities with regard to the author- reader relationship.) It covers the creation of new design ideas as well as the construction of linkages between these ideas. Clearly the locking and unlocking of fields facilitates the former, i.e. creation of new information. However, this new information will be meaningless if the latter is missing, i.e. linking this information. Basically concurrency control is a means to prevent members from writing in any inappropriate field in the authoring process. As authoring is perceived as the creation of linkages between different batches of information, the inclusion of the authoring of linkages in the mechanism of concurrency control becomes indispensable.

A concurrency control mechanism carries out the function of orchestrating the actions of PT members either as authors or readers. Thus messages posted to a node can be readily identified (Section 4.4.2). The most typical linking action is where one member tries to express his agreement with a design option proposed by another. This action may be represented by a short statement: "I agree with you" or "I agree with your Design Option X". The control mechanism has to distinguish the subject "I" and the object "you" or "your Design Option X" on one hand and to represent meaningfully the action "agree" on the other. In this connection, the concept developed previously from the model described in Figure 13 (Classification of relations between information objects) may be applied. That is to say, an information object owned by all PT members implies agreement. In the Collaboration Matrix, any information (say X1) as shown in the respective field of a member, implies his ownership of X1. Hence, whoever wishes to express his agreement with this particular issue has to put X1 in his own field as well.

Arising from this argument, four card buttons are built in the Collaboration Matrix against each of the card field (BSE, MS, SE and HM) namely:

i. BSE agrees with?

ii. MS agrees with?

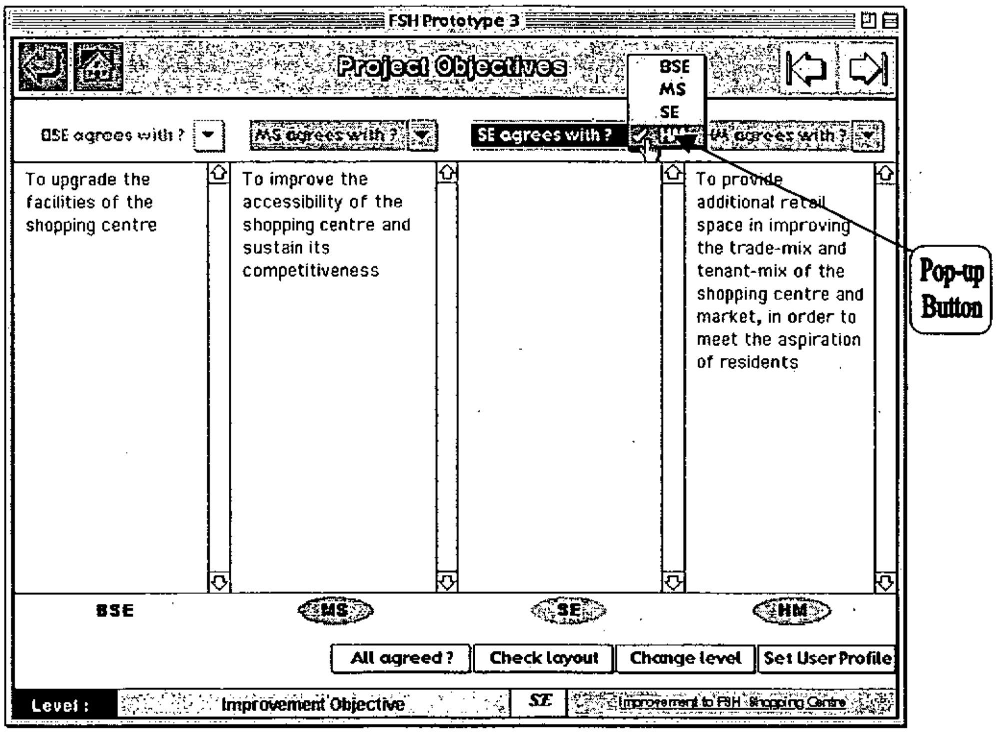
iii. SE agrees with?

iv. HM agrees with?

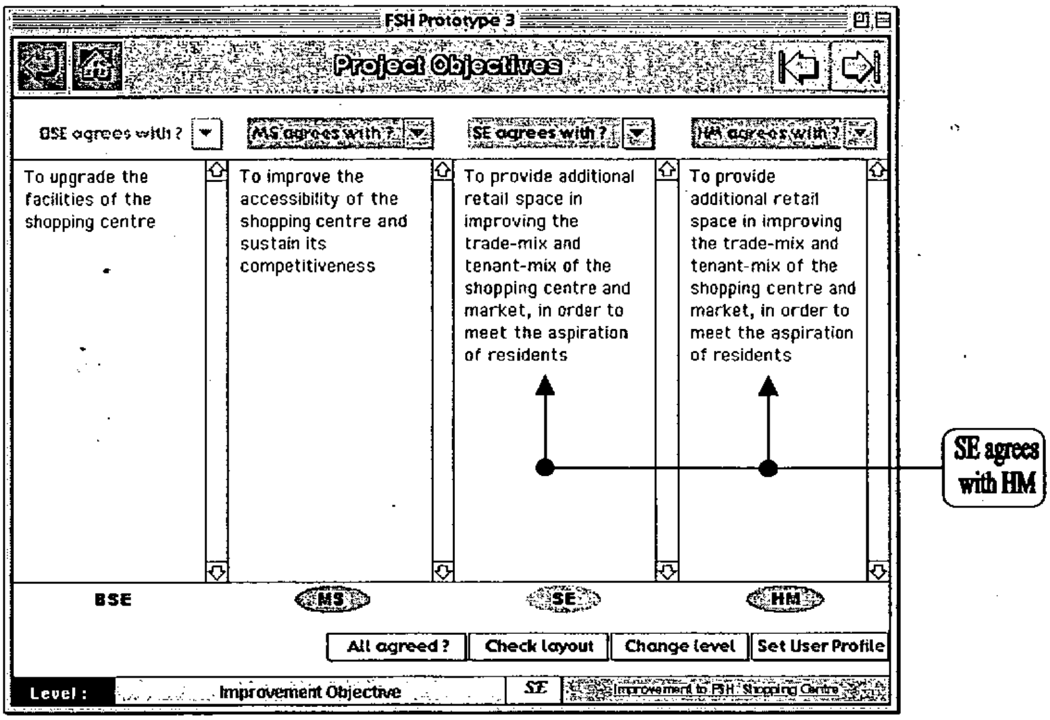
The purpose of these buttons is to facilitate a user's concurrence with the proposal of other PT members. These are "pop-up" buttons. When one of these buttons is clicked, a list of choices will appears. In this instance, the choices are the design options proposed by respective PT members, which are denoted by the abbreviations BSE, MS, SE and HM. When a user clicks one of these choices, the entire content of the field that corresponds to the choice will be copied to the field of the user, Figure 32. Similar to the logic of locking and unlocking of the four card fields, these four pop-up buttons are disabled whenever their respective field is locked in order to distinguish the roles of "I" and "You" in the process of authoring linkages. The pop-up button that has been enabled denotes "I" while the item that has been ticked represents "You". In this instance, SE is "I" and HM is "You". These pop-up buttons provide a means to realize the meaningful representation of the action "agree".

Control of "No Agreement" Situation

The pop-up buttons deal with the most ideal situation where all PT members concur regarding a particular design option. The scenario of total agreement is rare in practice, and has been discussed under Section 4.4.4. It is suggested that the control of the "no agreement" situation may be accomplished by breaking down the design items of the client's brief into smaller groups that correspond to the different design levels typically seen in the sequential development of a refurbishment project.



Before a Pop-up Button is clicked.



After a Pop-up Button is clicked.

Figure 32. Pop-up button facilitates the quest for agreement.

An improvement project for a HKHA shopping centre (abbreviated as FSH SC) has been selected as a reference project for the analysis of the development of a client's brief with a view to identifying the typical design levels. A major criterion to determine grouping of activities is to act "natural" in line with previous arguments, Figure 19. Design activities may be scheduled in a sequential but not necessarily natural order. For instance, a BSE may be asked to propose the type of lighting fittings before the project objective is defined. Although it is in a sequential order it is by no means natural. The study of the design activities of FSH SC may provide important clues for the defining of design levels in representing design options.

A design level may be defined in accordance with the chronological order of the design activities. In addition, the complexity of a design information item in terms of the representation of building facilities may indicate the design level. These two aspects are taken into account in the analysis of the FSH SC. The method of data collection is carried out by gathering all the documentation arising from the exchange of information between PT members. These include committee papers, memos, notes of design meeting, etc. According to the Notes of the 1st Case Meeting, three groups of information have been delineated including background information, improvement strategy and improvement proposals (major requirements) as shown in Appendix 2.

The background information is classified as the Standard Information that has been defined in the Basic Information Model (Figure 5). It will not be included in the client's brief and thus does not form any part of the CDHM. On the other hand, improvement strategy and improvement proposals are the first two design levels that can be identified. The information represented by these two levels, which dictates the overall direction of the improvement project, is conceptual. Typical examples are improvement objectives, addition of central air-conditioning, improvement to internal circulation, etc. It was thought that PT members would collaborate at these two levels for a relatively longer duration on the assumption that in the absence of any directions it is difficult, although not impossible, to propose further concrete design options. However, anecdotal evidence suggests that PT members very soon (less than a month after the proposed improvement strategy was introduced) extend their area of collaboration into specific design information. Typical examples are the proposed locations of new facilities, identification of particular facilities to be replaced, etc. Inevitably, a third design level has to be introduced, i.e. scope of work (location of major facilities). Typically, practice indicates that there is no direct relationship between the chronological order of the design documentation and the design level to which the documentation belongs. PT members typically author and/or interrogate information at any of the three design levels that have been identified since the commencement of the design process (the acquisition of client's brief).

It is observed that members seldom discuss design issues relating to the highest design level (i.e. improvement strategy or objective) except in major design meetings. On the contrary, members are inclined to deal with information at the second and the third level more frequently, where the information represents more tangible matters. Clearly members may not readily visualize a conceptual objective unless it can be manifested through various specific design proposals that are typically covered in the second and third design level. In fact, members' concern extends to areas that cover details such as construction materials by the time the first draft design brief is concluded. In this connection, it is necessary to add one more design level to reflect the discussion of such details as the choice of construction materials, sizing of plants, construction details, etc. In other words, four design levels may be defined in a descending order from the highest level of abstraction of a design proposal (improvement objectives) to the lowest level that describes details of a design option, Figure 33.

DESIGN LEVELS	DESIGN INFORMATION
Level 1	Improvement Objectives/ Strategy
Level 2	Major Requirements (e.g. new central A/C system, additional transformer house, additional escalators, additional retail space)
Level 3	Scope of Work (Location of major facilities)
Level 4	Design Details (System Sizing, Materials, Critical Construction Details)

Figure 33. The four design levels of CDHM.

The configuration of CDHM is constructed according to the four-level configuration. As a result, another card is constructed as an index card that facilitates members' access to the desired design level more readily. It accords with the "index structure", described in Figure 28, the cards in each design level are connected sequentially. The interface card that provides choices for jumping to a respective design level is shown in Figure 34. The choice of a member is also shown in a background field appearing in all cards (design level field), illustrated in Figure 31. This serves as a landmark for a member's navigation purpose. On the other hand, the presence of a design level in each card of CDHM indeed indicates members' focus on the current design activities. This can also be interrogated and adopted as a variable to fulfil certain control functions for navigation in CDHM. In other words, the design level field provides threefold functions:

i. "index structure" for managing "no agreement" situation,

ii. landmark to facilitate navigation and

iii. input variable of scripts to implement specified control function.

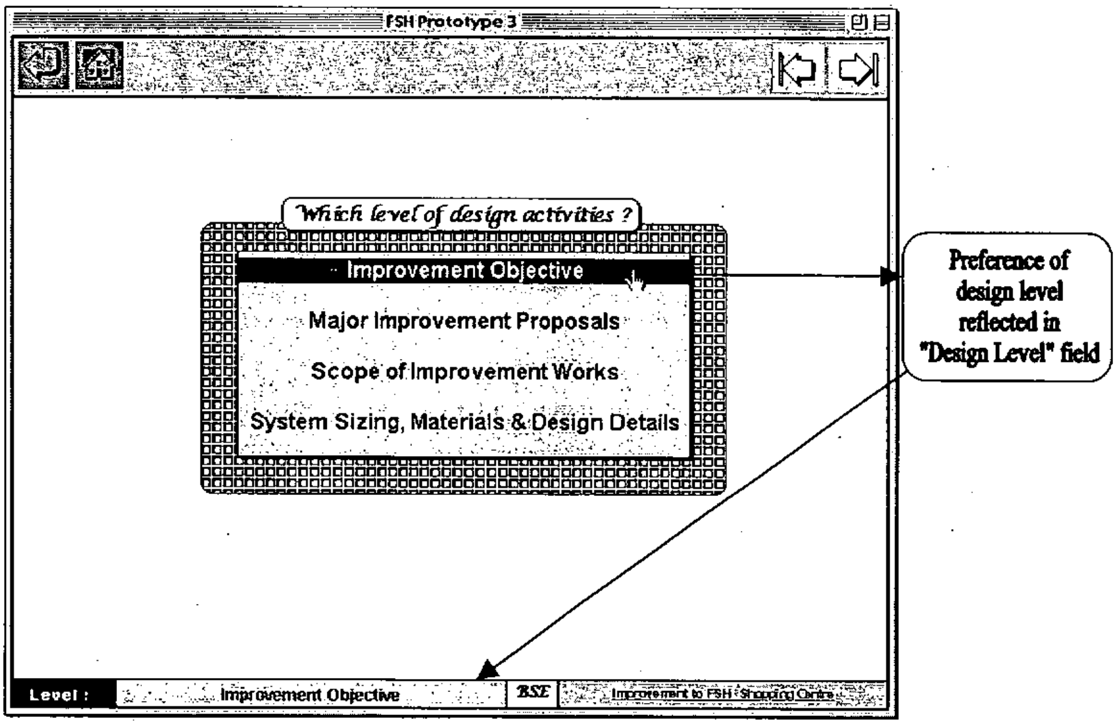


Figure 34 Interface card for choosing design level preference.

With the aid of the four-level configuration, collaboration between members may be concluded more readily on the basis of a respective level. A conclusion could be in total agreement or with different proposals as options. Disregarding whether it is an agreement or design option, such design information has to be archived in order to end a collaboration cycle and to facilitate subsequent retrieval. Therefore, another button is constructed for this purpose namely "archive". When an "archive" button is activated, all the four card fields of the collaboration matrix are locked, meaning the design information of this card can no longer be updated. For ease of identification, this card is stamped with the word "*ARCHIVED*", Figure 35. Since this archived card is placed at the same design level as the one that it was authored, it can be searched and interrogated in a manner similar to the authoring process.

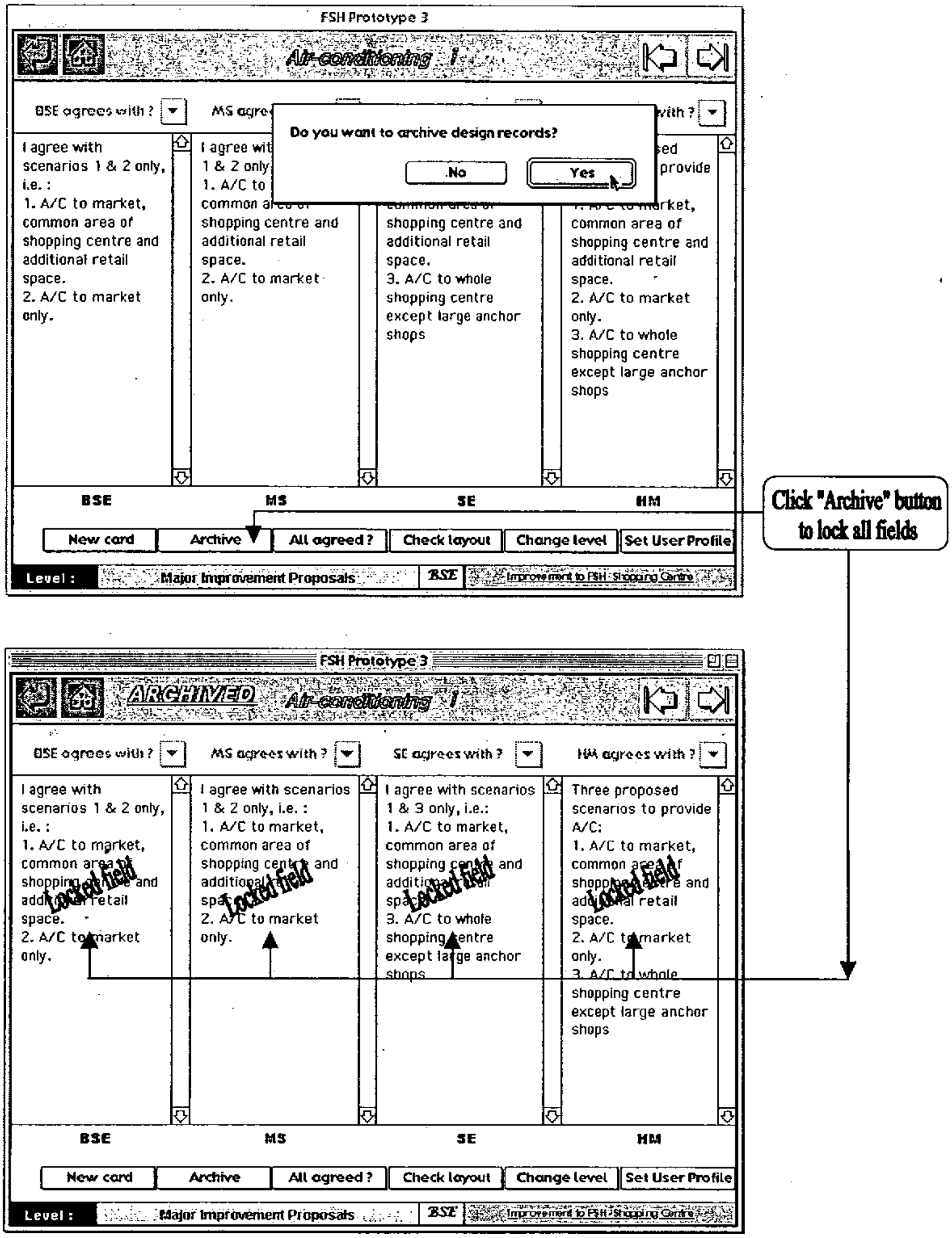


Figure 35. A collaboration matrix is archived.

In the absence of any purpose-built control function, there is nothing to prevent a member from accessing those cards that do not belong to the design level selected by him when he first started his navigation journey through CDHM. Such a scenario is acceptable when a member is using the browsing function only. However, when he intends to carry out an authoring function, such an inconsistency may undermine the effectiveness in the pursuit of an agreement between PT members. For example, a BSE has selected the "improvement objective" level and has not exchanged ideas with other members at this level. He then moves to another level, the "major improvement proposal", where he browses other member's proposals. If he makes a proposal at this level which does not tally with his previously declared level, other members might not be aware of the shift of the focus of discussion. As a result, additional effort is required to draw the attention of other members to the newly picked design level and away from the former. While it may be a more pragmatic approach to rely on the self-discipline of members to maintain consistency in the exchange of design proposals, it could be worthwhile to provide certain automated functions that can maintain consistency in the archiving of design proposals. It will be examined in the following Section regarding "managing design changes".

Managing Design Changes

It has been explained in Section 4.4.5 how the request for a design change may be scrutinized by checking it against two categories of design proposals, i.e. improvement items that have been agreed by all members as well as those without consensus yet converted to different design options. The criteria of checking is to identify any connection between the proposed design change and the design information base of CDHM with a view to ensuring the three-tier authorization principle will never be trespassed on. Therefore, the integrity of the data in CDHM is vital to the validity of the decision in such a request for change.

However, it is important to maintain consistency between the design level and the authoring behaviour of PT members. Archiving activities can be seen as part of the authoring task because they result in new information in the sense that members agree to end their discussion or debate with respect to a particular information item. Subsequently, it is necessary to "purify" archived information, preferably in a proactive manner. The tactic is to caution members to think twice before they decide to archive any information item. Thus archiving must be consistent with both the wishes of the author and the design decision level.

The archiving constraint is realized by modifying the script of the "archive" button in such a way that it compares the design level field against the design level of the card in question. Archiving is forbidden if these two levels disagree. (Archived cards provide an information set of a higher quality against which members may manage design changes more effectively.) Archiving has to be used in a reasonable manner. There are two extremes of unreasonable application, which may render archiving meaningless. Firstly, members exhibit great reservation in concluding their discussion and hence the archived information set becomes empty. On the other hand, members may be reluctant to compromise and thus may choose to archive most of the improvement proposals not yet agreed to by all members. Both scenarios are unfavourable in terms of effective collaboration between members. Such a shortcoming may not be readily overcome by scripting to attain a higher degree of automation in the converging of diverse design ideas. The justification is based on the perception that collaboration is ultimately dependent on the personal choice of a member, who certainly has his own right to compromise or to insist on his view. Nevertheless, information has been captured under the four-level CDHM where members can carry on their discussion under a common protocol irrespective of whether the data are archived or not.

In the example of FSF SC as shown in Appendix 2, agreement to the first draft design brief has been reached. Under such circumstances, all the improvement proposals can be archived and become a high quality information set. Subsequent development of this project indicates that this information set provides the necessary basis for the major design changes that occur afterwards. In this case, the original design brief suggests that central air-conditioning will not be provided to the shopping centre. However, a decision of the management (Shopping Centre Improvement Committee – SCIC, one component of the three-tier authorization hierarchy) reverses the design brief, resulting in the provision of central air-conditioning, the first unpredictable change. CDHM should have no difficulty in managing all these changes in terms of the ongoing authoring as well as eventual tracking of changes.

4.5 The architecture of CDHM

The construction of CDHM is subject to the perception of "The distinction between structuring 'in the large' and authoring 'in the small'". The collaboration matrix previously described in Section 4.4.7 is seen as the "small", i.e. the area where PT members may carry out authoring activities. The implementation of the "small" concept through the collaboration matrix has been analyzed and elaborated. The results of the analysis suggest that the CDHM may be configured in four design levels, which provides a basis for structuring the "large". Each level will be represented by a chain of collaboration matrices featuring an "index structure".

Owing to the limited amount of data that can be carried by a card or a collaboration matrix, the need to define and create sub-levels pertaining to each level, except the "improvement objective" level, is inevitable. Again the records of the design activities of a typical project (FSH SH as reported in Appendix 2) provide essential data for the establishment of these sub-levels. It is observed that that the frequency of exchanging views between PT members at the "improvement objective" level is relatively low in comparison with that of the second and third levels. As a result, the actual amount of information at this level is so limited that the need of sub-levels is not imminent. On the other hand, arising from the 1st and 2nd case meeting, the topics raised in these meetings can be readily classified to delineate the sub-levels accordingly. The proposed sub-levels are as shown below:

1. Air-conditioning
2. Transformer house
3. Lighting
4. Vertical transportation
5. Fire services
6. Retail space
7. Signage

8. Finishes
9. External façade
10. False ceiling and
11. Miscellaneous facilities.

It is also observed that level 2 (major improvement proposals), level 3 (scope of improvement work) and level 4 (system sizing, materials and detail design) basically share the same system of sub-levels. Furthermore, the frequency with which members refer to a specific level subsides at level 4 in contrast to those reported at level 2 and level 3 up to the moment when the client's brief is concluded. Indeed any further detailed design information will be reflected in the design drawings as well as the formal contract specifications at the lower design levels where the degree of abstraction is no longer significant. It is essential to recall that CDHM is mandated to primarily handle the client's brief, i.e., design details as reference information embodying the design intent at level 2 and level 3 in the main body of the brief.

As regards the representation of the sub-levels in HyperCard, it may be a one-to-one mapping or many-to-one mapping in respect of the "card vs. sub-level" relation, meaning one card for one sub-level or several cards for one sub-level. It can be demonstrated that the argument regarding the control of a "no agreement" situation for the four design levels is equally applicable to the sub-levels. It will enhance the collaboration process in the pursuit of an agreement knowing that PT members can more easily compromise at each sub-level. By the same token, other arguments and iterations similar to those previous mentioned can be developed for the sub-levels situation provided each sub-level is denoted by a collaboration matrix. This implies that the architecture of CDHM is essentially a framework of connected collaboration matrices. Under each design level, an interface card which is similar to that for the design level (Figure 34) is constructed to provide express links to specific sub-levels. This framework is shown in Figure 36 schematically.

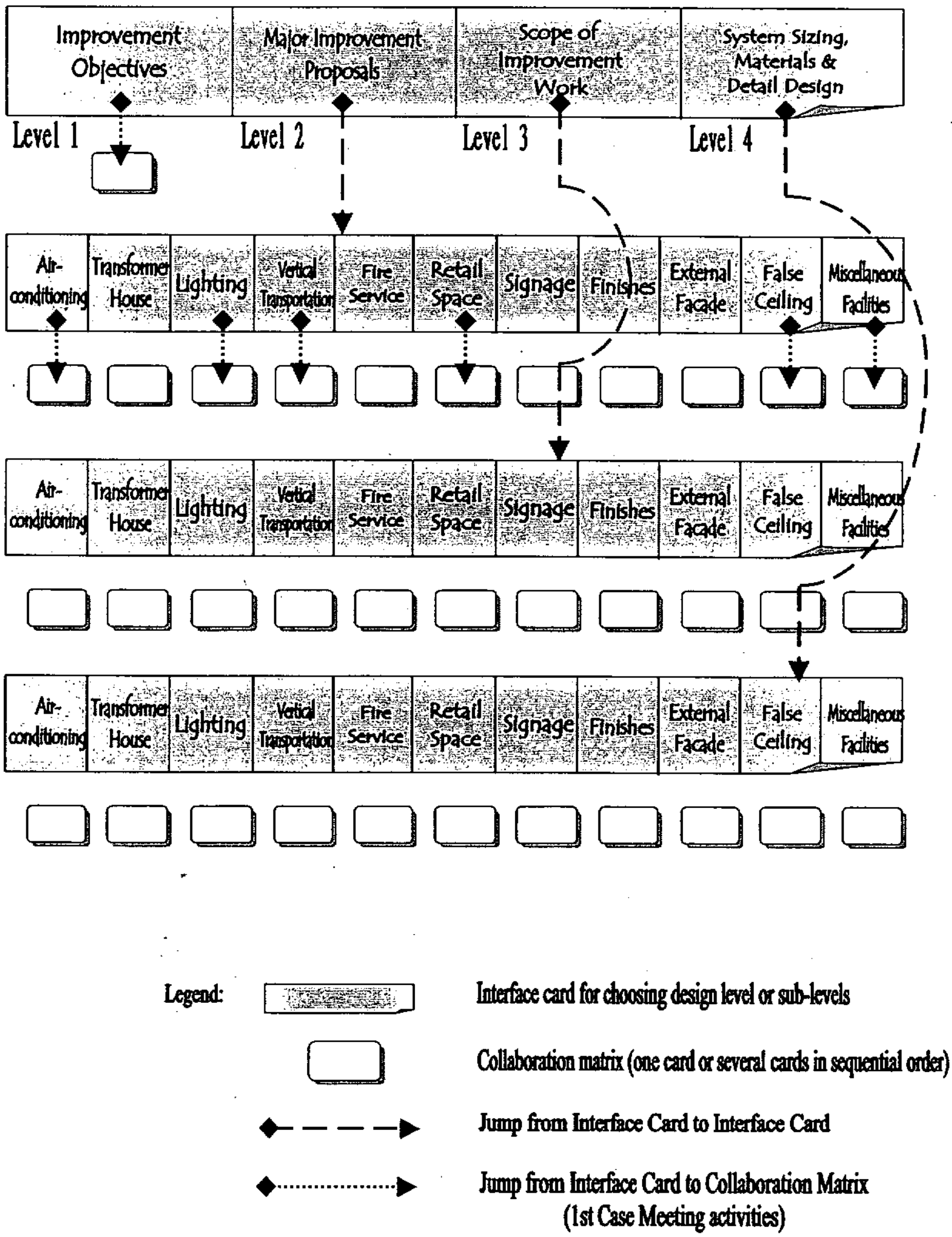


Figure 36. Framework of the CDHM Architecture.

In Figure 36, the locations of the collaboration matrices in relation to the design levels and sub-levels are shown. For illustration purposes, the collaborative design activities during the 1st Case Meeting of FSH SC are also presented, navigation paths being superimposed on the framework. Other activities - reported in Appendix 2 - can be translated into different navigation paths against the CDHM framework. It should be noted that the CDHM framework summarizes the results of all the research work as well as analyses the client's brief for the refurbishment exercise. This is founded on the Preliminary Collaboration Model (Figure 9) which represents the initial perception of PT members. Nevertheless, the framework as presented in Figure 36 is a relatively crude approximation as far as a smooth navigation is concerned. For example, it lacks facilities to allow a user to provide instant access to change design levels anywhere in CDHM. Hence, supporting functions need to be identified and built into CDHM.

4.6 Supporting functions

Arising from the need to control the "no agreement" situation, an "archive" button is constructed, Figure 35. (Other functions have also been identified for the proper operation of a collaboration matrix.) In most cases, a user has to go to another card such as the interface card, i.e., the only location where choices of respective criteria for subsequent navigation can be made. In addition, requirements that do not have any direct relationship to the development of a client's brief; yet are essential for enhancing productivity needs to be accommodated. Typical examples are the creation of additional collaboration matrices under the same design sub-level and the checking of the contents of a collaboration matrix in respect of their agreement status.

The foregoing review of the various functions suggests that additional buttons are required mainly to facilitate the authoring process. In this regard, four card buttons are constructed, namely:

i. "Set User Profile" button,
ii. "Change level" button,
iii. "All agreed?" button and
iv. "New card" button.

The "Set User Profile" button provides a direct connection from the current collaboration matrix to the interface card (Figure 30) where a user can log in his identity. Under normal circumstances, this interface card is usually the first card that a user will access when he opens CDHM. (He is required to log in his identity before he navigates to other cards.) However, if a user chooses to carry out browsing only without any authoring, formally logging in may be unnecessary. However, if a user wishes to go back and log in his own identity authoring can be sanctioned.

The "Change Level" button enables a user to jump from a collaboration matrix to the interface card to choose design levels (Figure 34). Strictly speaking, a user is not obliged to maintain the consistency between an active collaboration matrix and the design level (as shown in the "design level" field) if he is conversant with the organization of CDHM and he is not going to archive any information. In other words, the "Change Level" button can bring a user to the required design level in CDHM with no barrier to stop him from going to collaboration matrices of other design levels while the display of the "design level" remains unchanged. This maintains the fluidity of CDHM in such a way that a member's freedom to access and handle information may be optimized against the effectiveness of collaboration in the quest for an agreement. Another point is that this button is not directly applicable to sub-levels.

The "All agreed?" button checks the four card fields of a collaboration matrix to compare the texts that have been written by PT members. If all the texts are identical it implies an agreement between members and the collaboration matrix in question will be automatically stamped "AGREED!". Up to this stage, a member may click the "Archive" button to prevent any further change to this card.

"The "New Card" button creates a new collaboration matrix immediately after the one currently displayed Both belong to the same sub-level. They are identical except that the four card fields (representing members design input) are empty. This enables design proposals that are of the same sub-level to be discussed. For example, under the sub-level "Air-conditioning" of Level 3, it is necessary to determine proposed location of the new chiller plant. It is also necessary to delineate the exact area of the shopping centre to be air-conditioned. Under such circumstances, a separate collaboration matrix would streamline the process. It may be argued that the situation can be better managed if a "sub-sub-level" is defined instead of the creation of a new card on an ad hoc basis, i.e. another level below sub-level. However, the addition of the third level has to be justified by at least two factors. Firstly, the amount as well as the variety of the information reported in Appendix 2 shows no genuine need for the third level. There are only a few collaboration matrices under each item of a sub-level. Secondly, the proliferation of levels will increase the complexity of CDHM, which in turn may undermine collaboration effectiveness. Therefore, the third level is not discounted.

As well as these buttons for authoring, several buttons that enable a more efficient navigation in the CDHM are included. For example, the four background buttons shown in Figure 31 provide the basic facilities for maneuvring between design levels. In addition, a "Check layout" button is constructed as a card button for accessing reference layouts or sketches. A typical arrangement of these buttons is shown in Figure 37. The operation of the "All agreed?" button is also explained in Figure 38.

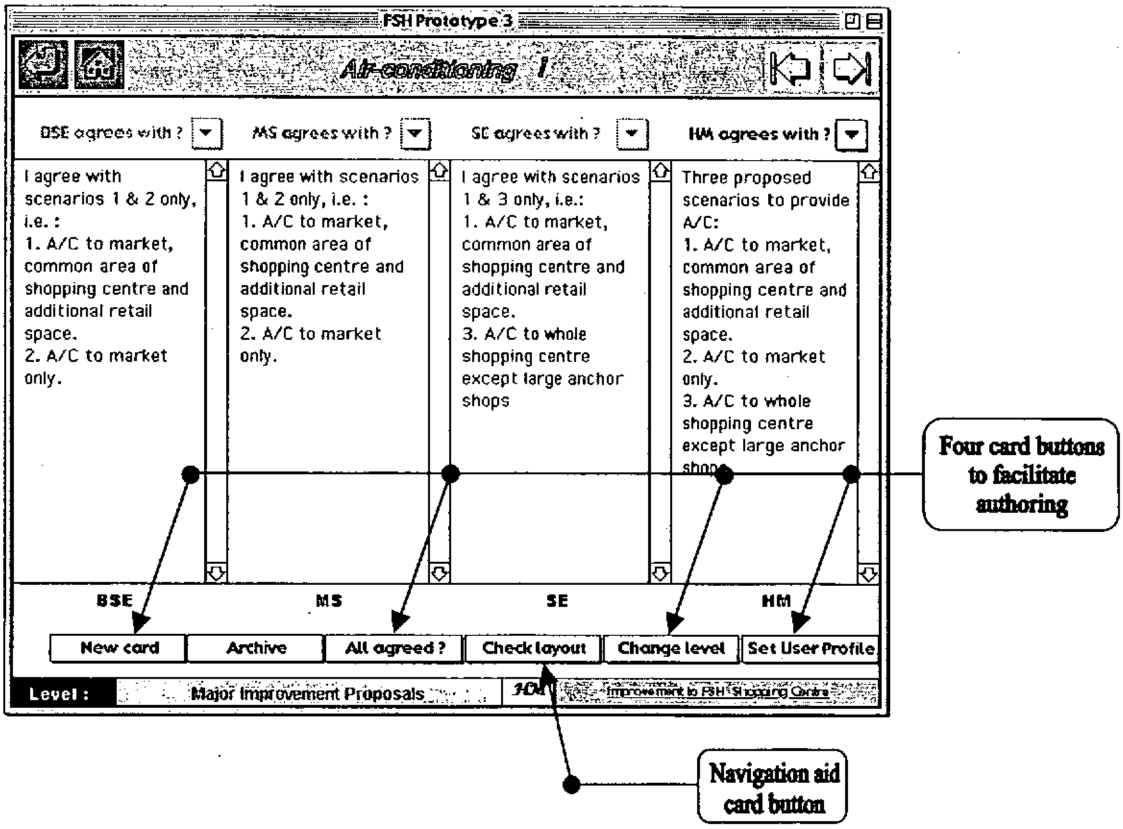


Figure 37. Additional buttons to support authoring and navigation.

4.7 Preliminary evaluation of CDHM

By now, the construction of CDHM is basically complete. The core component of CDHM is the collaboration matrix which has been built to carry out three main tasks, i.e., (a) concurrency control, (b) control of the "no agreement " situation and (c) managing design changes.

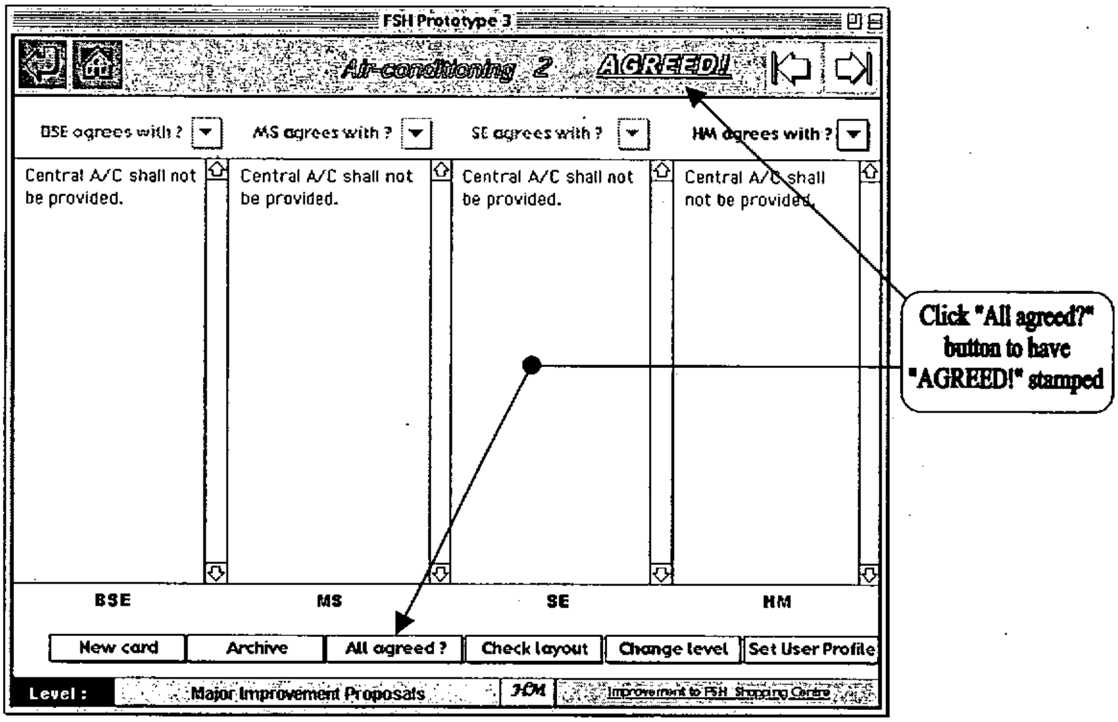


Figure 38. An "agreed" collaboration matrix.

Given the prototype nature of the CDHM, it was decided not to test a live project. This is justified on the basis of the numerous uncertainties and variables that fall beyond the scope of this research project. These may have significant impact on the effectiveness in achieving an agreement. For example, whether a member is computer literate or not is one consideration. Unfortunately, the impact of these factors cannot be readily quantified. Thus the review or preliminary evaluation can only be done by mimicking the situation where members exchange their CDHM without the actual involvement of any member.

The distribution and reception of information among PT members can be carried out in a "sequential" mode or "non-sequential" (parallel) mode, shown in Figure 39. For the sake of evaluation, it is necessary to see what would happen when a member carries out his collaborative activities (either browsing or authoring) and dispatches the updated CDHM to other members. To illustrate, a typical "walk-through" that distinguishes the two different modes is shown.

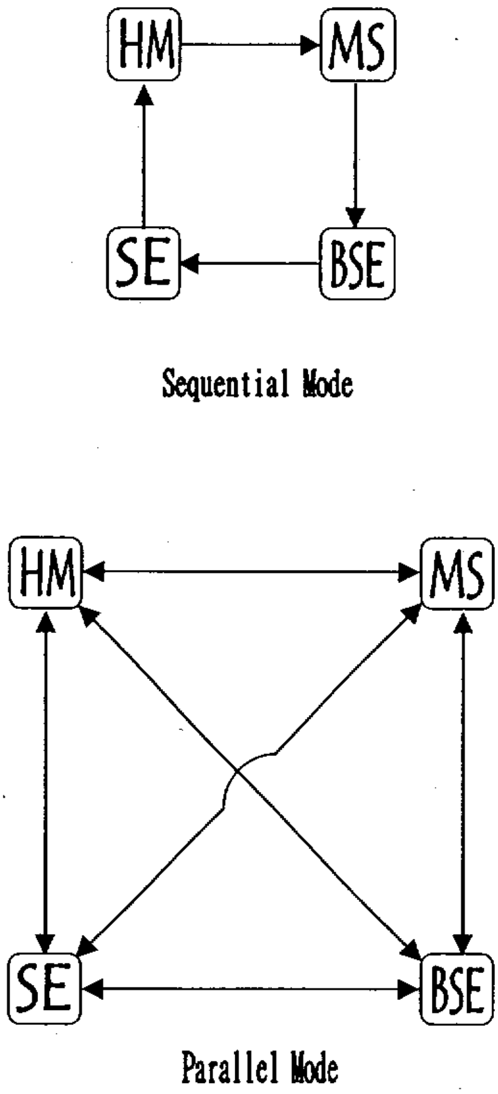


Figure 39. Two different modes for distributing CDHM: Sequential vs. Parallel.

Under the sequential mode, let us assume that HM is the first PT member to kick-off the collaboration process at a particular sub-level, say air-conditioning. After HM has entered his proposal (e.g. chiller plant location) in his collaboration matrix card field, he passes the CDHM to MS. MS then repeats the same process, except only his own card field can be updated. BSE and SE will repeat the same procedure. As soon as the members "Agreed", a discussion follows on the area that will be covered by the new air-conditioning system. A new card or new collaboration matrix is then created. Again, HM will take the lead by creating a new collaboration matrix using the "New Card" button. As previously, the cycle repeats according to the order: MS, BSE, SE and back to HM. So far CDHM can meet the preset requirements as far as "concurrency control" is concerned

Now BSE would like to refine the agreement regarding the proposed chiller plant by attaching a sketch layout to show more precisely the proposed location. Similar to the previous order, the matrix is passed to the SE who in turn may wish to change the layout to show a different arrangement. Unfortunately, there is only one "Check Layout" button that can be used by members. Consequently the sketch layout attached by BSE is likely to be replaced by the one suggested by SE and the suggestion of BSE is lost. In this instance, the "Check Layout " button is likely to corrupt CDHM in respect of "concurrency control".

Unfortunately a sequential mode is not common. Members typically choose to "broadcast" their proposals to all other members in the shortest time period, i.e. adopting parallel distribution of information. Again, the collaboration process is evaluated by means of the "walk-through" approach. Similar to before, HM starts the process by adding his proposal to his field in the collaboration matrix and passes the CDHM to MS, BSE and MS simultaneously. Each member receives it and starts his authoring in the designated area of CDHM only, i.e. his own field in a collaboration matrix. An updated CDHM is then "broadcast" to other members. Similar to the sequential mode, a new collaboration matrix is created for another new topic under the same sub-level using the "New Card" button.

The effect of the "New Card" is examined in more detail. For instance, let us assume the BSE is working on a collaboration matrix under the Air-conditioning sub-level. Let us call this CM-A/C1. Now he wishes to switch over to another topic under the Air-conditioning sub-level and a new collaboration matrix is created namely CM-A/C2. The updated CDHM is broadcast to other members. Meanwhile, it is possible that one of the receiving members (e.g. MS) may have duplicated the action of the BSE, i.e. created another new collaboration matrix under a different sub-level, say fire service. Let us call this new collaboration matrix CM-FS2. There is nothing to prevent MS from sending his updated CDHM (with CM-FS2 added) to all other members before BSE's CDHM is received. Clearly either one of the newly added collaboration matrices will be deleted depending on whose CDHM arrives first. That is to say, if a member, say HM receives the CDHM of BSE before that of MS, CM-A/C2 will disappear in HM's CDHM. Obviously the requirement to provide concurrency control has not been met when operating in a parallel mode since a new collaboration matrix has been created adding to the preset ones.

Shortcomings in concurrency control have an unfavourable effect on the control of the "no agreement" situation. They also impact the management of design changes in an indirect manner. The validity of any agreement reached is questionable if members are unable to ensure the integrity of the information from which an agreement is derived. It follows that archived information that belongs to an unresolved design proposal also suffers. The deterioration in the quality of design information has in turn increased the difficulties in tracking design changes simply because a member cannot distinguish differences between a design change and missing information.

It has been suggested that unsatisfactory performance of concurrency control gives rise to the alleged deterioration in the quality of information. The maintenance of the quality of archived information is seen as a crucial factor in facilitating design change management. Hence an interlocking mechanism is built in CDHM to ensure that members can only archive information that tallies with the "design level" field. However, under the parallel mode, the "Archive" button is liable to suffer from the same shortcoming encountered in the "New Card" button situation. Both buttons yield new information that falls beyond the four card fields owned by HM, MS, BSE and SE respectively. The collaboration matrix CM-A/C1 is again taken as an example. BSE and MS are looking at their own CM-A/C1's that differ with regard to the contents of the four card fields. If both archive their CM-A/C1 at the same time, confusion would arise. Thus some sort of access control has to be built into the "Archive" button.

The "walk-through" approach is considered again. When a member receives a CDHM, he can easily identify what has been changed if the size of CDHM is small and if he has a good memory. However, for a CDHM of significant size, a PT member may not be able to identify any changes even when he has a very good memory. For any active collaboration matrix, the four card fields belonging to respective PT members can be updated many times without some members being fully aware of what has ocurred. As a result, some sort of notification system has to be in place in order to draw the attention of members to the latest change status as soon as practicable.

In summary, further enhancement to CDHM has been identified, namely:

i. concurrency control to "Check Layout" button,
ii. concurrency control to "New Card" button,
iii. concurrency control to "Archive" button and
iv. notification mechanism to alert receiving member the last design changes.

4.8 Enhanced CDHM

The "New Card" button is considered first. A problem occurs when more than one member attempts to create a new collaboration matrix under the parallel mode of collaboration. One simple solution is to restrict the access right to "New Card" button to one member only. If this is the case, the next question is "Who has the right?". Once again, it is worthwhile to recall Pohl's argument, which suggests that a meaningful representation of the real world object is the prerequisite for a collaborative problem-solving environment. Inevitably, the operation of the Project Team in handling design information has to be revisited, notably in areas regarding the receiving and dispatching of design files.

In HKHA, each refurbishment project is given a file with a dedicated file number. Each file is essentially a paper folder that holds all the relevant documents such as memos, committee papers, drawings, etc. filed in a chronological order. The administration of this file is undertaken by people who do not belong to the project team, i.e. the General Office. The GO's main duties are the creation of new files, registering/ filing documents, tracking file movement among PT members and the disposal of obsolete files. If PT members are perceived as real world objects that have been represented in CDHM in one way or another, the administration people (abbreviated as ADM) must be represented as well for the sake of completeness. Consequently, it is reasonable to let ADM be the only authorized person to press the "New Card" button. However, the existing structure of CDHM lacks a communication channel between PT members and ADM. This is required to convey the message asking for a new collaboration matrix. Therefore, the need of a notification mechanism is essential.

A HKHA file folder is made up of three parts:

i. folder cover where member can input the identity of receiving person,
ii. index showing the list of documents that have been exchanged between members and
iii. documents that have been registered in accordance with the index.

Within the index, very often people write a short note (alternatively known as "minutes") to supplement the information conveyed by the respective documents in the folder. These minutes serve as a notification, drawing the attention of the receiving persons to the arrival of new messages, and important points within the documents. Therefore, it is logical to suggest that something similar to the index system should be included in CDHM with a view to providing the notification function.

Pursuant to the above analysis, two real world objects have been identified, i.e. administration people (ADM) and the index. As regards ADM, the most meaningful representation is to modify the Interface card for the logging in of Identity (Figure 30) by providing one more choice in addition to the existing ones (BSE, MS, SE and HM), i.e. ADM. This is to cope with the situation where ADM is expected to maintain the exclusive right to create a new card. To this end, the interface card is modified as shown in Figure 40. The normal operating sequence is that the "New Card" button is normally disabled unless the display of the Identity field is "ADM".

With regard to the "Archive" button, it is not practical to impose restrictions that enable only one authorized member to activate the "Archive" button for the whole CDHM. However, the requirement arising from the consideration of concurrency control is that each collaboration matrix should be archived by one member only. If the collaboration mode is sequential, no additional scripting is required for the "Archive" button. The main concern takes place under parallel collaboration where members may simultaneously carry out archiving to the same collaboration matrix. One alternative arrangement is to restrict the access right of members to the "Archive" button in relation to the choice of design level or sub-level. For example, for Level 1 and Level 2, HM - the client's representative - may be the most appropriate to be charged with the responsibility of deciding whether a collaboration matrix should be archived or not. Similarly, for Level 3 and Level 4, each member should be responsible for his own design sub-levels that belong to his area of expertise. This being the case, BSE becomes the only member with the authority to archive collaboration matrix under air-conditioning design sub-level of Level 3 and Level 4, and MS has jurisdiction over signage, so on and so forth.

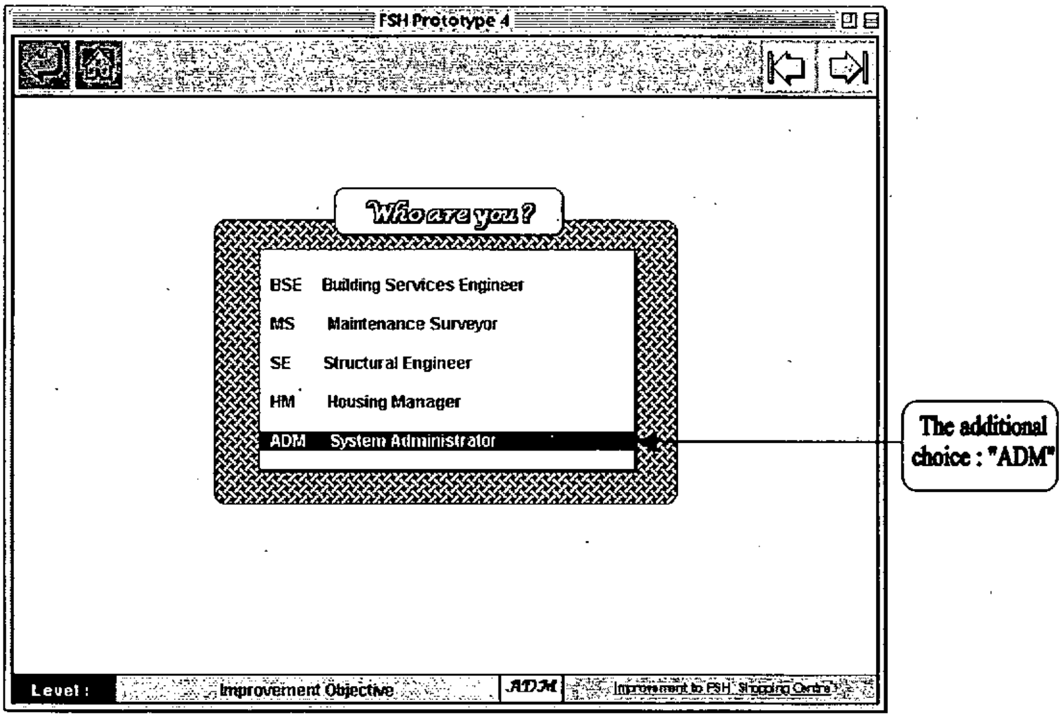


Figure 40. Modified Interface Card with ADM added.

The remaining enhancement in respect of concurrency control arises from the "Check Layout" button. The concept and technique adopted in controlling the access right to the four card fields can be directly applied. That is to say, the "Check Layout" button is converted into four separate buttons belonging to respective members (excluding ADM). Each of these additional buttons will perform a full function when a specific card field is unlocked. (Full function means that it may jump to the required card showing the required layout drawing or allow a member to create a link to the desired layout. Whenever the specific card field is locked, this new button can only go the preset card without any authority to create a new link.) The enhanced concurrency control is illustrated in Figure 41.

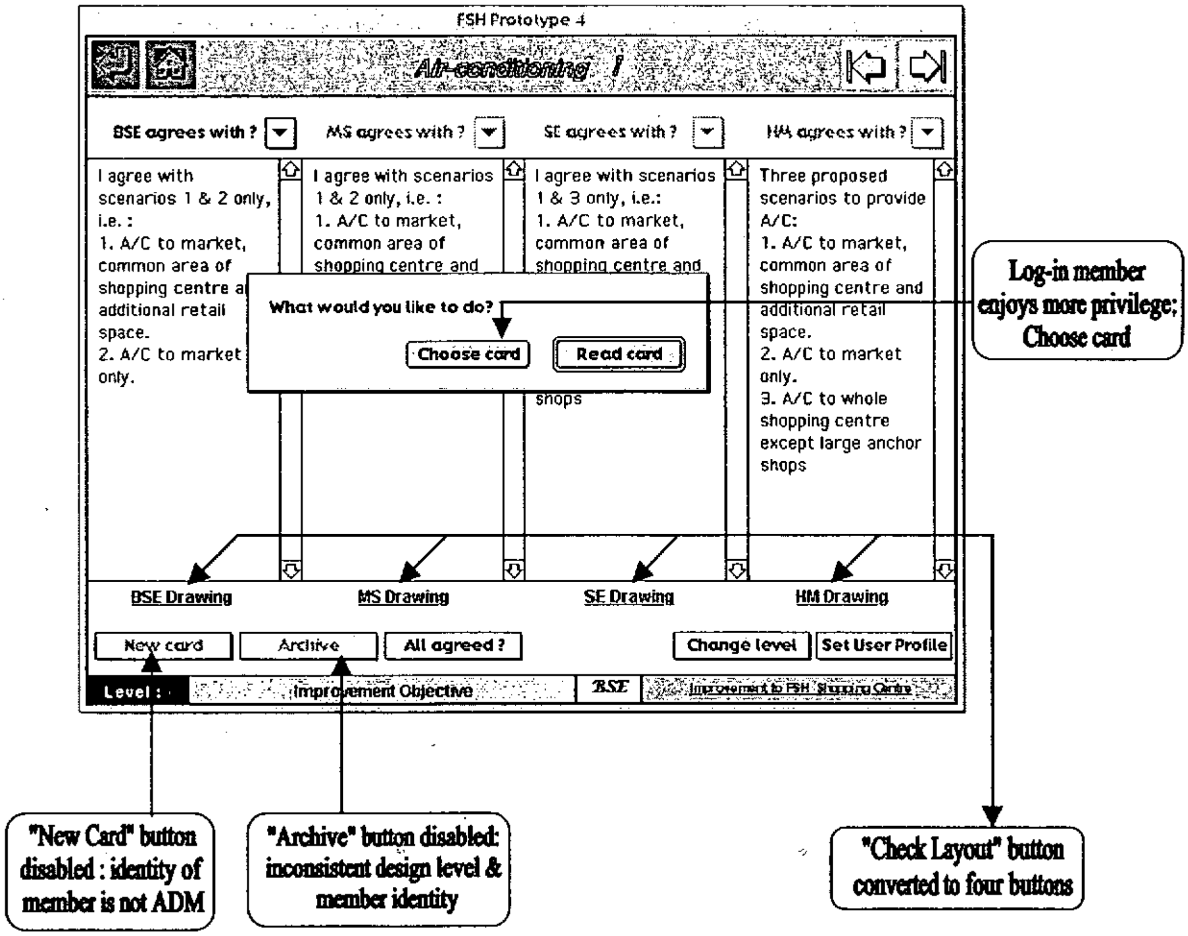


Figure 41. Enhanced concurrency control.

The four new buttons that replaced the "Check Layout" button will take a user to specific cards to show the corresponding layouts. Any card carrying these layouts is subject to constraints in respect of concurrency control similar to those encountered in the collaboration matrix. In other words, a member who is not the author of a layout is not allowed to make any change to it. Such a requirement is met by adding script to the card in question in such a way that the HyperCard user level is adjusted to browsing only whenever the identity shown in the identity field does not tally with the owner of the card.

Finally, the second real world object that has been identified is the "index". Index is understood as a separate sheet that records all transactions of correspondence between members in a chronological order. The representation of the "index" in CDHM is implemented by adding extra cards that precede the main body of CDHM, i.e. the full set of collaboration matrices. The typical arrangement of an index card is shown in Figure 42. It should be noted that for each item of comment made by a member, there is a "click" button by which an express link is or can be made to a specific collaboration matrix. The index cards are built as four different groups, one for each PT member. Each group of cards is locked or unlocked depending on the identity of a user, which is the same as the logic adopted for the four card fields in a collaboration matrix. Again this provides a consistent level of control throughout the entire CDHM. An "index card" button is built for each collaboration matrix to provide direct connection to the "index".

A "new card" button is also provided for each Index card, which is necessary for the situation where an existing Index card is full and an additional card is required. The same logic is adopted for a collaboration matrix, i.e., the "new card" button can only be operated by ADM.

Figure 43 illustrates these additions.

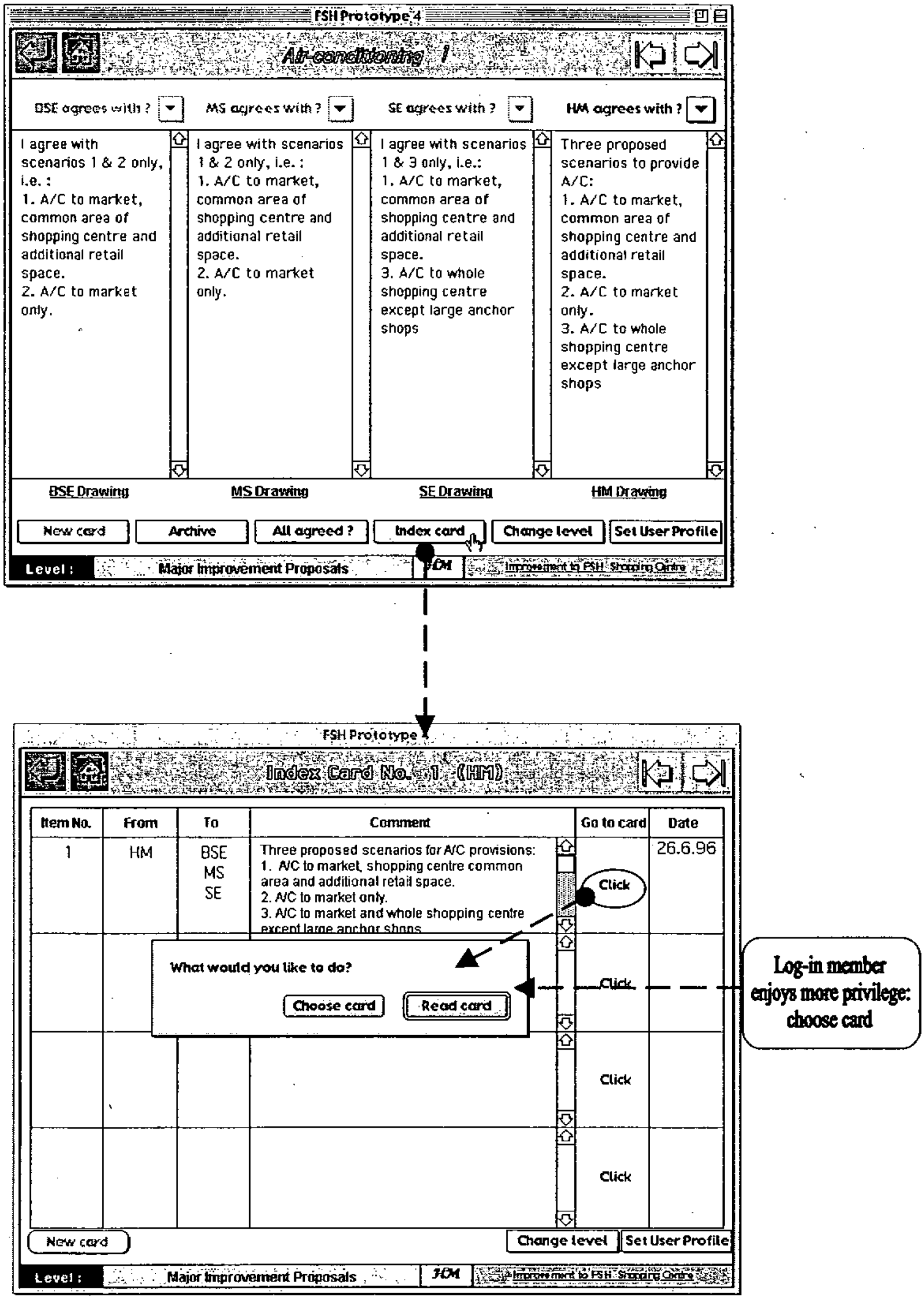


Figure 42. Access to a typical Index Card from collaboration matrix.

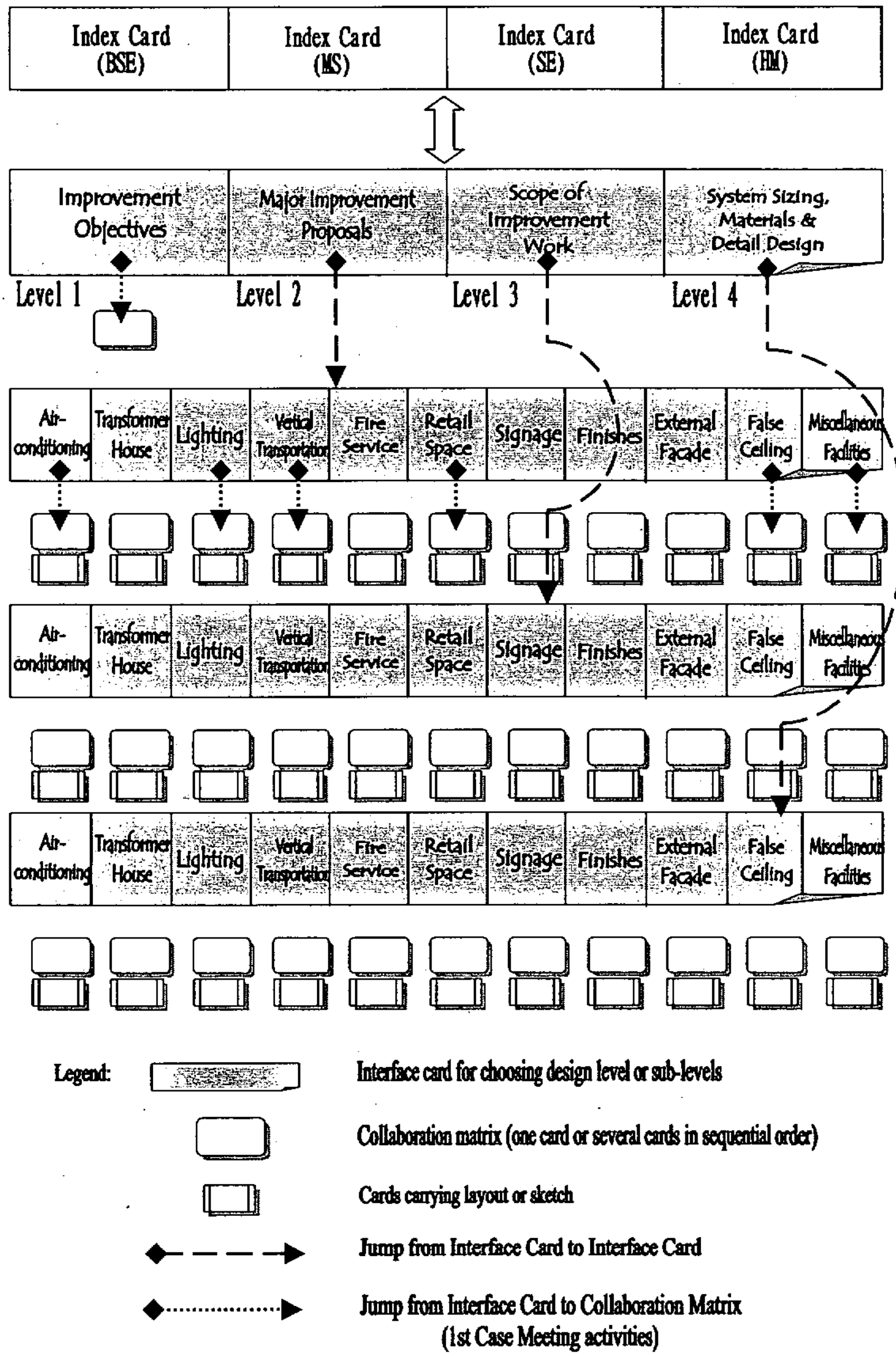


Figure 43. Framework of an enhanced CDHM.

CHAPTER FIVE

Chapter 5: Evaluation

5.1 Objectives of evaluation

Different concepts and techniques have been explored and tested, which give rise to the development of CDHM. CDHM is perceived as a means of evaluating the proposed solutions pertaining to the core argument. Therefore, the primary objective of an evaluation is: to review the entire research strategy as well as the design of CDHM in order to confirm the extent to which such an argument is valid.

With regard to the purpose of the research, it is legitimate to mainly focus the evaluation of CDHM on the basic concepts and the design approaches. It should be noted that CDHM has been constructed and tested as a prototype. The arrangement and implementation vary depending on the types of authoring tools being applied. The objective of an evaluation may be stated, i.e.,

- the proposed data structure has to be verified with regard to its validity in representing the design process, and
- the effectiveness of the proposed hypermedia model in organizing those data in question has to be assessed.

However, it is extremely difficult, though not impossible, to define any quantifiable parameters to measure the extent to which these two secondary objectives are met. Consequently concepts and practices that prevail in the multimedia industry with regard to evaluation, may be borrowed, on the understanding that multimedia is a superset of hypermedia (Figure 12).

It has been suggested that the multimedia system does not have a strong tradition of testing, which leads to the consideration of having different types of data collected for evaluation, i.e. quantitative vs. qualitative, objective vs. subjective, summative vs. formative, etc. [England, E. and Finney, A., 1996]. In this connection, England & Finney have put forward a variety of approaches for testing and evaluation from initial conceptual design stage to final release of a product. As far as CDHM is concerned, those quoted for early development stages, including concept testing, peer review and prototyping, are likely to be relevant.

Concept testing means trying out the main project ideas on selected groups of people representative of the intended user group. The ideas may be presented in a paper walkthrough or through discussion. Peer review provides a faster approach to testing these concepts by getting colleagues to bring their experience to bear on the evaluation of the concepts of design. Finally, prototyping is a mock-up of several of the key features of the project. It is designed to obtained feedback on the general look and operation of the design during development. Clearly these different approaches are qualitative and have to be further elaborated.

With regard to the evaluation of CDHM, the intended user group in the concept testing and the colleagues in the peer review overlap. Under such circumstances, these two different evaluation exercises may be carried out simultaneously. Therefore, CDHM was presented to a group of building services engineers experienced with refurbishment projects. Finally, CDHM itself is a prototype that manifests the main features of the research argument. However, it has been constructed based on the results deduced from the conceptualized process of the collaborative design activities. Therefore, pursuant to the primary objective of an evaluation, it is reasonable to carry out a demonstration of the implementation of CDHM using real project data.

5.2 Concept testing and peer review

The project team responsible for the refurbishment of shopping centres in the Housing Authority were invited to a CDHM presentation. The team comprised Chartered Building Services Engineers, Chartered Mechanical Engineers as well as technical staff who assist the engineers in their design work. The presentation was broadly divided into three parts:

- introduction of the concept of CDHM,
- live demonstration of CDHM, and lastly
- panel discussion and feedback.

The general response was positive. The theme of the research project is considered to be relevant to the tasks of the project team. There is no disagreement about the concept of the CDHM architecture. No additional level or sub-level is suggested. One major comment is that CDHM is exactly the right tool for project team members to retrieve archived design information with confidence because it performs reliably in the locating of design information.

However, the limited capability of CDHM in handling graphic information is seen as a shortcoming. Furthermore, the need of a PT member to take up the role of "editor" is briefly discussed. There is no conclusion as to which member should be the editor. Apparently members favour a more flexible arrangement in the course of developing a design brief.

5.3 Demonstration of CDHM with real project data

The CDHM has been constructed as a prototype by observing the design activities of a typical refurbishment project in a real situation. The results of the observation have been analyzed and transformed into a hypermedia structure explicitly. However, it is necessary to test the essential functions of the CDHM prototype by "running" it using typical project data. It may be argued that the prototype should be "run" under a live environment in order to find out the whole truth. (By "live" it is meant that the activities of a project team will be observed throughout the period during which the CDHM is applied in developing the client's brief of a particular project.) Unfortunately the length of such a period will typically last for one year. Obviously the "live" option is by no means a viable approach as far as time is concerned. The major concern for this part of an evaluation is to obtain relevant data to "run" the prototype. In fact, such data is available from the existing manual filing system where all correspondence and committee papers of a project are archived. Hence, it is argued, project information may be extracted from these files in such a way that CDHM could be "run" to simulate the "live" arrangement.

However, although testing using archive project data requires much less time and resources for testing, an inherent constraint is evident since all the response of respective PT members regarding hands-on experience with CDHM is ignored. To overcome this difficulty all project data has been input into CDHM by one person only. This person plays the roles of all four PT members in an alternate manner (for easy reference, this testing method is therefore named "Role-play Method"). Nevertheless, such a gap can be bridged to a certain extent by conducting the "peer review" that would form part of the entire evaluation exercise. The testing using Role-play Method is sub-divided into the following steps:

- collect copies of archived project information in relation to the formulation of the first version of a client's brief,

- arrange these copies in a chronological order,
- input project information into CDHM according to the ownership of such information,
- count the number of collaboration matrices that have been created under respective design sub-level,
- count the number of collaboration matrices that are stamped "Agreed" and "Archived" and
- compare these "Agreed" and " Archived" items against the original version of client's brief that was developed without CDHM.

As far as the last step is concerned, the purpose is to assess the representation of a client's brief under the CDHM environment in terms of its clarity and adequacy. A full set of cards created in CDHM is shown in Appendix 3. The cards represent a typical navigation path through CDHM as well as the sequence of exchanging CDHM between PT members. This latter part represents the negotiation about a new transformer house location.

The background and particulars of the project that have been used to "run" CDHM is briefly described. The name of the shopping centre has been abbreviated to FSH. The building has a life of about 14 years and serves a population of about 34,000 residents. The shopping centre is a 3-storey building with a retail area of about 7610 m^2 (IFA) close to the bus terminus and provides one Chinese Restaurant, 2 fast food shops and 38 limited trades shops to cater for the daily needs of the residents. A market with 86 stalls is situated on the ground floor of the carpark building adjacent to the shopping centre. The cooked food stalls are located over a separate freestanding terrace (refuse collection point underneath). The client is of the opinion that the finishes are obsolete, that the commercial facilities in the centre are inadequate to meet the rising demand of shoppers and that it is difficult to compete with the private shopping centres in close vicinity to FSH. The estimated cost for the FSH refurbishment project is 75 million Hong Kong dollars.

During the demonstration, several additional buttons have been created to facilitate access to Index Cards, Figure 44. During the development phase it is found that confusion arises during authoring and navigation because of the similarity between collaboration matrices belonging to the same building system (such as air-conditioning) yet on different Levels. Under such circumstances, each collaboration matrix is denoted with its respective Level number, Figure 45.

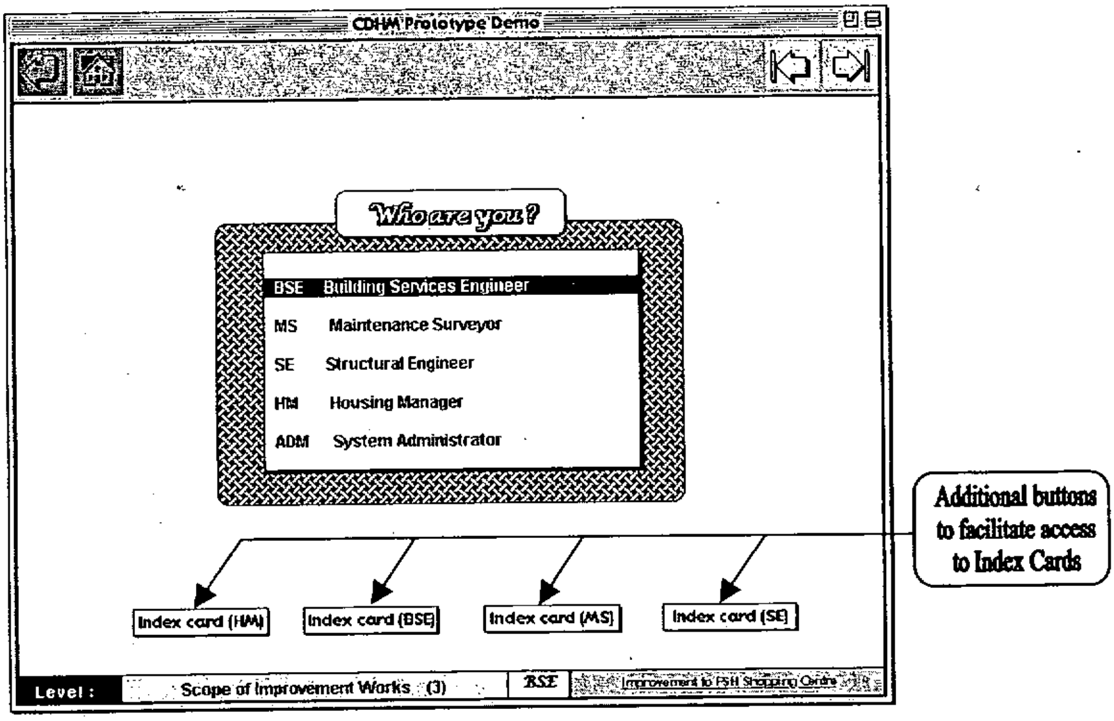


Figure 44. Additional buttons to access Index Cards.

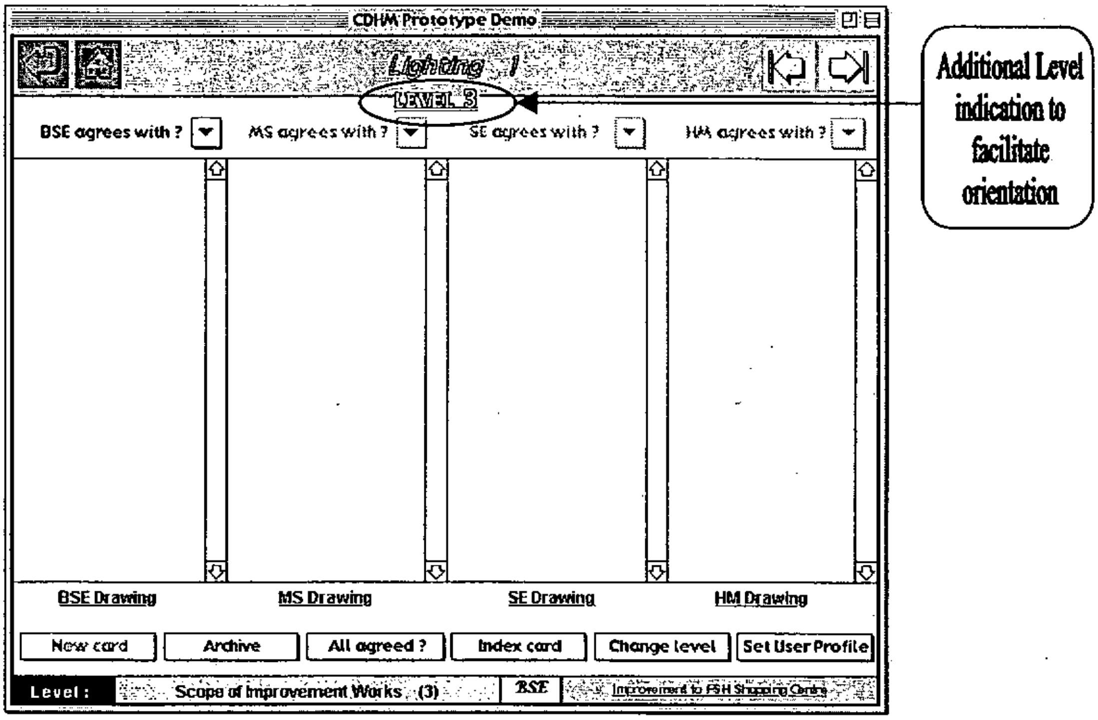
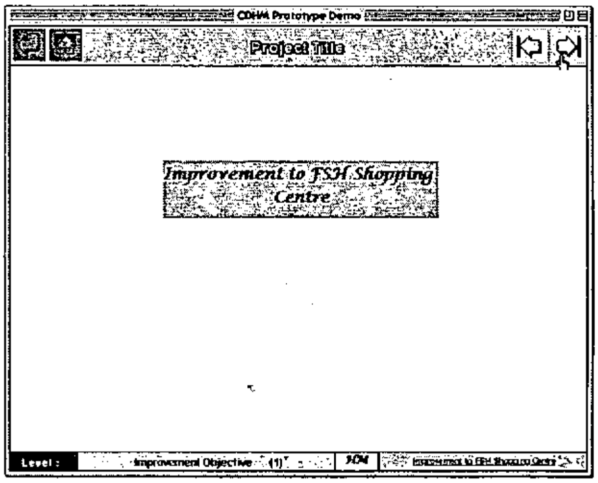
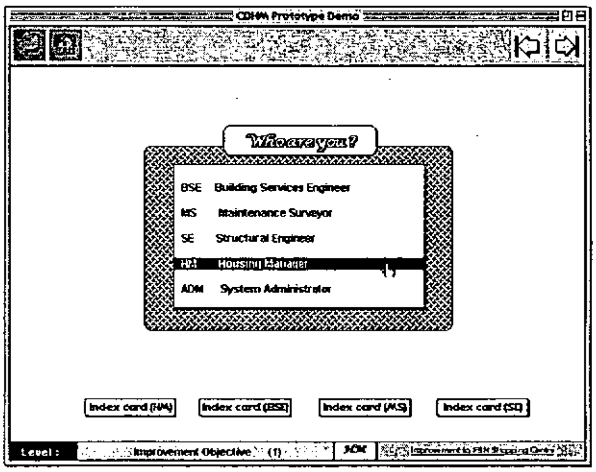


Figure 45. Additional level indication.

5.3.1 Typical navigation paths undertaken by PT members

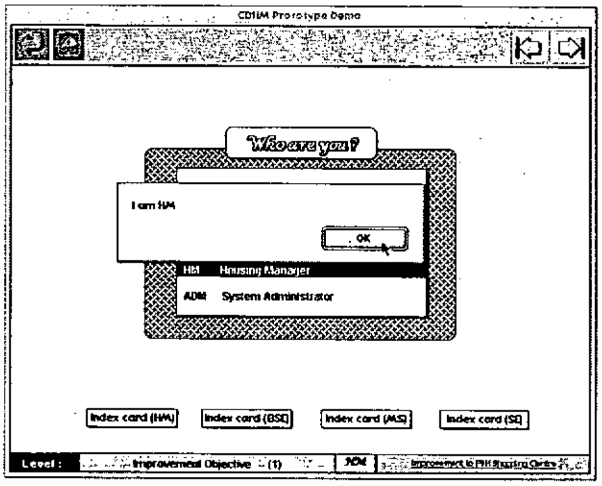
An example of determining the location of the new transormer house

ROUND 1: HM to present the first set of proposals

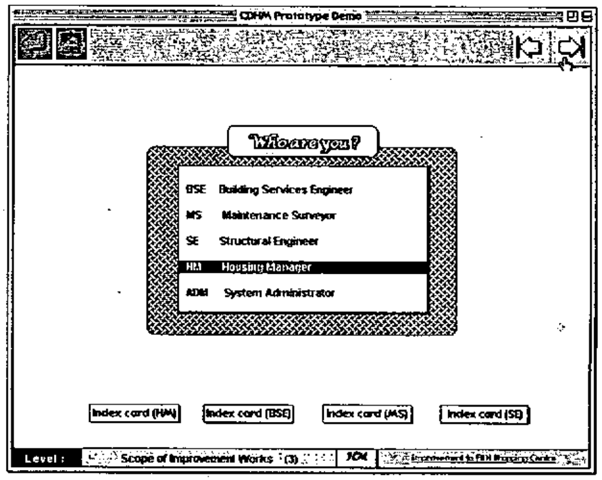
Action Member	CDHM Display Sequence
HM	
HM	

Remarks: "☝" stands for one mouse click.

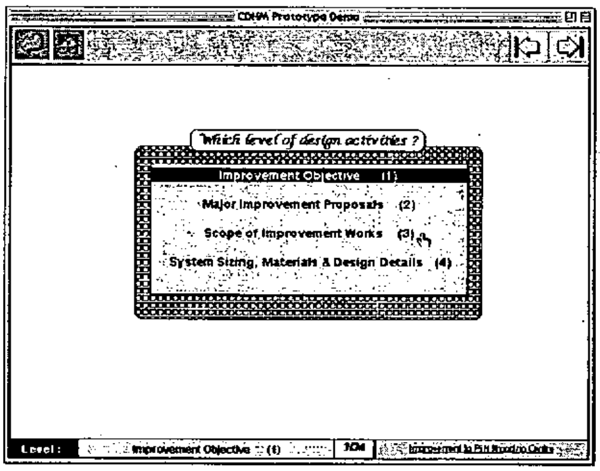
HM


CDHM Prototype Demo
Who are you?
I am HM
OK
HM Housing Manager
ADM System Administrator
Index card (HM)
Index card (BSE)
Index card (MS)
Index card (SE)
Level :
Improvement Objective (1)

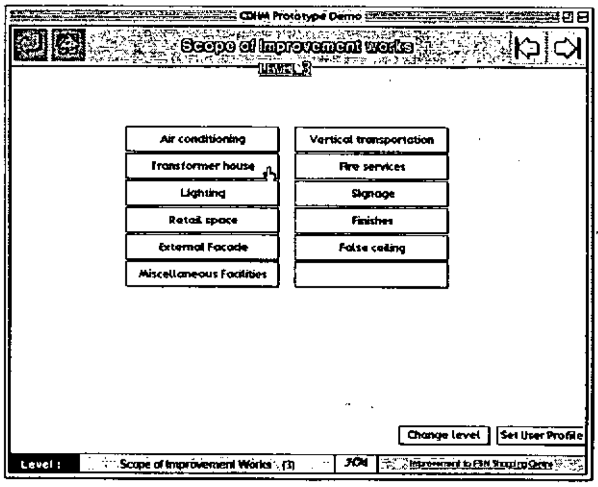
HM


CDHM Prototype Demo
Who are you?
BSE Building Services Engineer
MS Maintenance Surveyor
SE Structural Engineer
HM Housing Manager
ADM System Administrator
Index card (HM)
Index card (BSE)
Index card (MS)
Index card (SE)
Level :
Scope of Improvement Works (3)

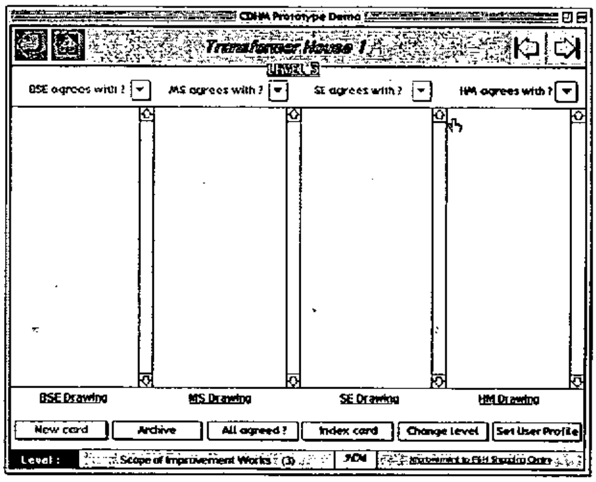
HM


CDHM Prototype Demo
Which level of design activities ?
Improvement Objective (1)
Major Improvement Proposals (2)
Scope of Improvement Works (3)
System Sizing, Materials & Design Details (4)
Level :
Improvement Objective (1)

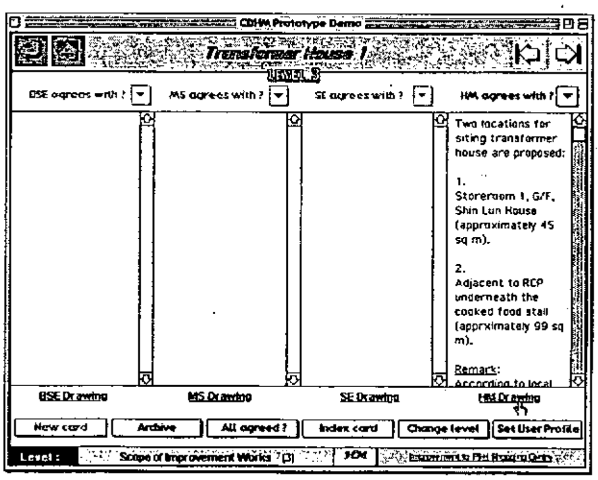
HM


CDHM Prototype Demo
Scope of Improvement works
Air conditioning
Transformer house
Lighting
Retail space
External Facade
Miscellaneous Facilities
Vertical transportation
Fire services
Signage
Finishes
False ceiling
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

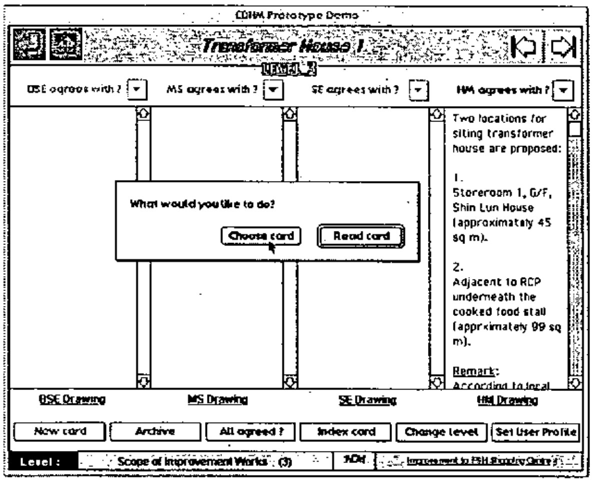
HM


CDHM Prototype Demo
Transformer House 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

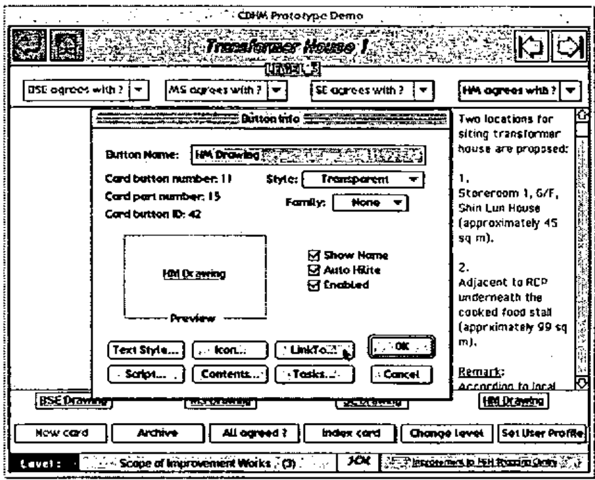
HM


CDHM Prototype Demo
Transformer House 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Two locations for siting transformer house are proposed:
1.
Storeroom 1, G/F, Shin Lun House (approximately 45 sq m).
2.
Adjacent to RCP underneath the cooked food stall (apprximately 99 sq m).
Remarks:
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

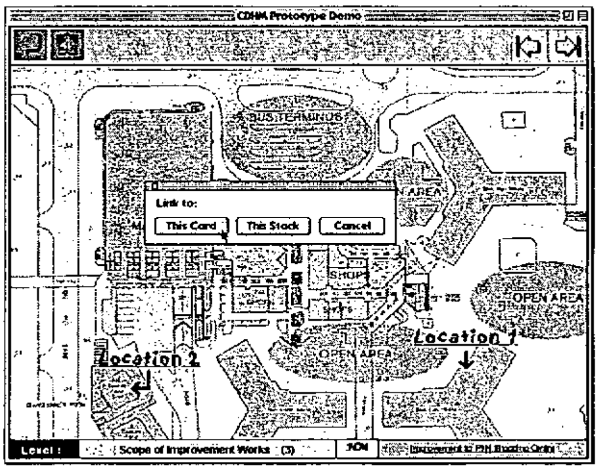
HM


CDHM Prototype Demo
Transformer House 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
What would you like to do?
Choose card
Read card
Two locations for siting transformer house are proposed:
1.
Storeroom 1, G/F, Shin Lun House (approximately 45 sq m).
2.
Adjacent to RCP underneath the cooked food stall (apprximately 99 sq m).
Remark:
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

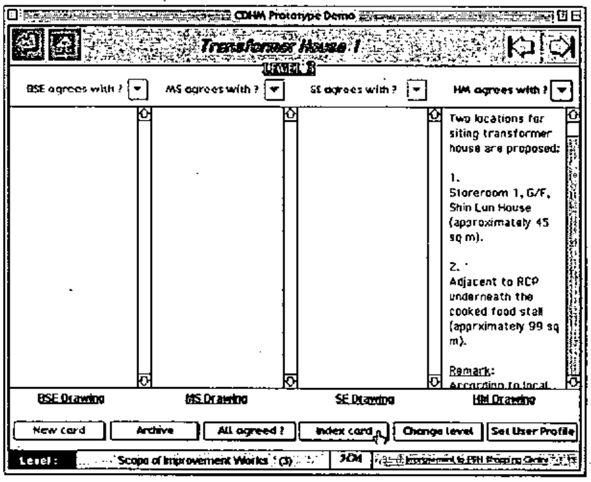
HM


CDHM Prototype Demo
Transformer House 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Button Info
Button Name:
HM Drawing
Card button number: 11
Card part number: 15
Card button ID: 42
Style:
Transparent
Family:
None
HM Drawing
Preview
Show Name
Auto Hilite
Enabled
Text Style...
Icon...
LinkTo...
OK
Script...
Contents...
Tasks...
Cancel
Two locations for siting transformer house are proposed:
1.
Storeroom 1, G/F, Shin Lun House (approximately 45 sq m).
2.
Adjacent to RCP underneath the cooked food stall (apprximately 99 sq m).
Remark:
BSE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

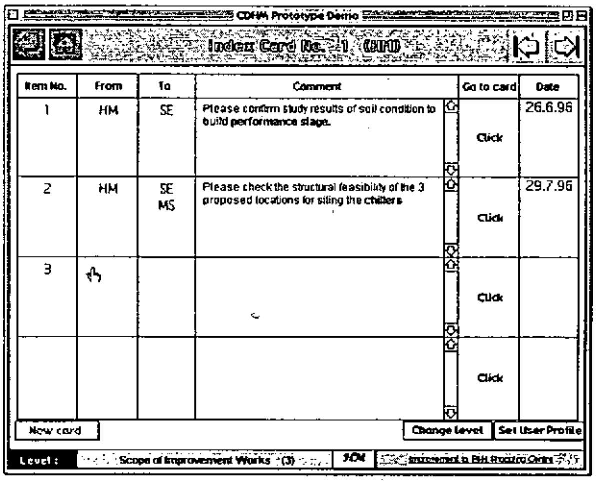
HM


CDHM Prototype Demo
BUS TERMINUS
AREA
Link to:
This Card
This Stack
Cancel
SHOP
OPEN AREA
OPEN AREA
Location 1
Location 2
Level :
Scope of Improvement Works (3)

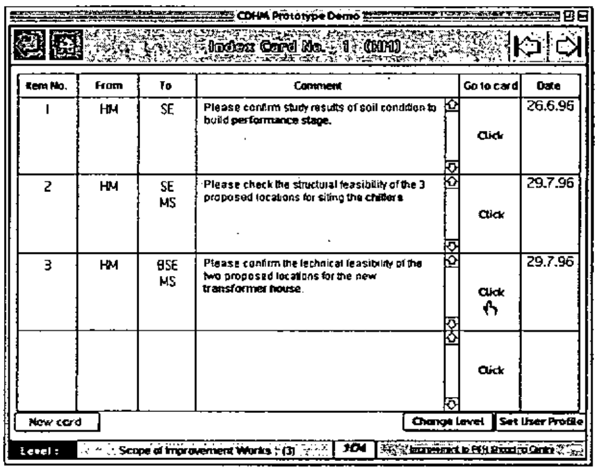
HM


CDHM Prototype Demo
Transformer House 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Two locations for siting transformer house are proposed:
1.
Storeroom 1, G/F, Shin Lun House (approximately 45 sq m).
2.
Adjacent to RCP underneath the cooked food stall (apprximately 99 sq m).
Remark:
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

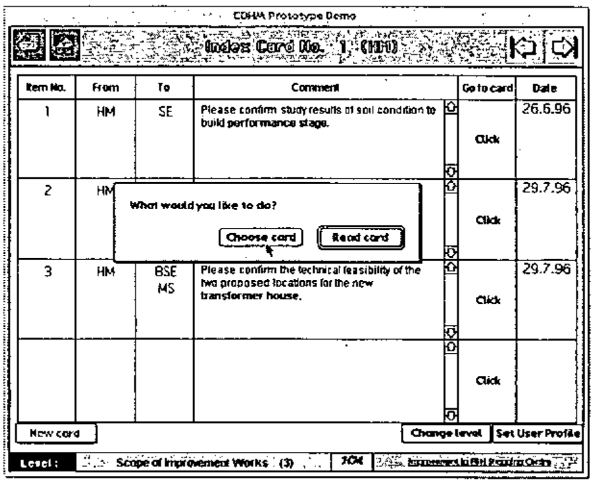
HM


CDHM Prototype Demo
Item No.
From
To
Comment
Go to card
Date
1
HM
SE
Please confirm study results of soil condition to build performance stage.
Click
26.6.96
2
HM
SE
MS
Please check the structural feasibility of the 3 proposed locations for siting the chillers.
Click
29.7.96
3
Click
Click
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

HM

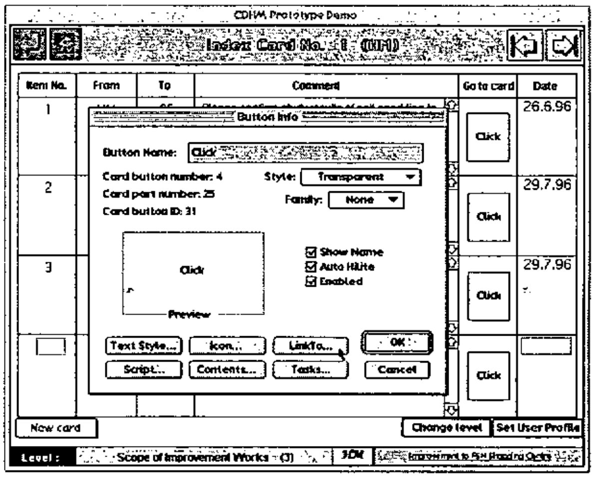

CDHM Prototype Demo
Item No.
From
To
Comment
Go to card
Date
1
HM
SE
Please confirm study results of soil condition to build performance stage.
Click
26.6.96
2
HM
SE
MS
Please check the structural feasibility of the 3 proposed locations for siting the chillers.
Click
29.7.96
3
HM
BSE
MS
Please confirm the technical feasibility of the two proposed locations for the new transformer house.
Click
29.7.96
Click
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

HM



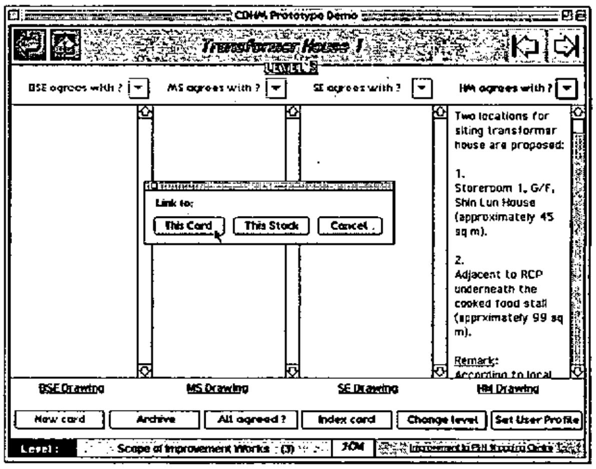
CDHM Prototype Demo
Index Card No. 1 (HM)
Item No.
From
To
Comment
Go to card
Date
1
HM
SE
Please confirm study results of soil condition to build performance stage.
Click
26.6.96
2
29.7.96
What would you like to do?
Choose card
Read card
3
HM
BSE
MS
Please confirm the technical feasibility of the two proposed locations for the new transformer house.
29.7.96
New card
Change level
Set User Profile
Level:
Scope of Improvement Works (3)

HM



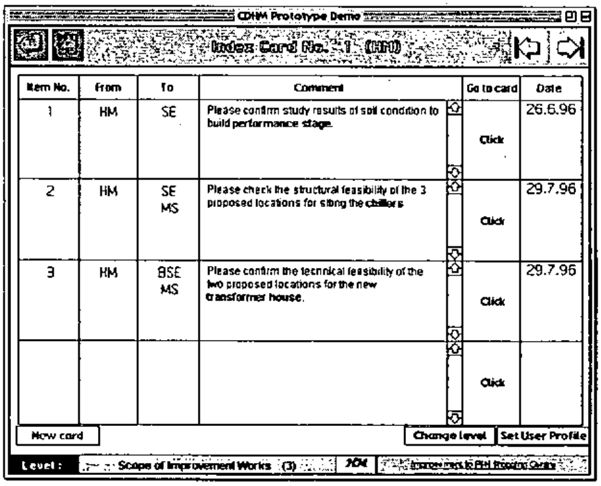
CDHM Prototype Demo
Index Card No. 1 (HM)
Item No.
From
To
Comment
Go to card
Date
26.6.96
29.7.96
29.7.96
Button Info
Button Name:
Card button number: 4
Card part number: 25
Card button ID: 31
Style:
Transparent
Family:
None
Show Name
Auto Hilite
Enabled
Preview
Text Style...
Icon...
LinkTo...
OK
Script...
Contents...
Tasks...
Cancel
New card
Change level
Set User Profile
Level:
Scope of Improvement Works (3)

HM



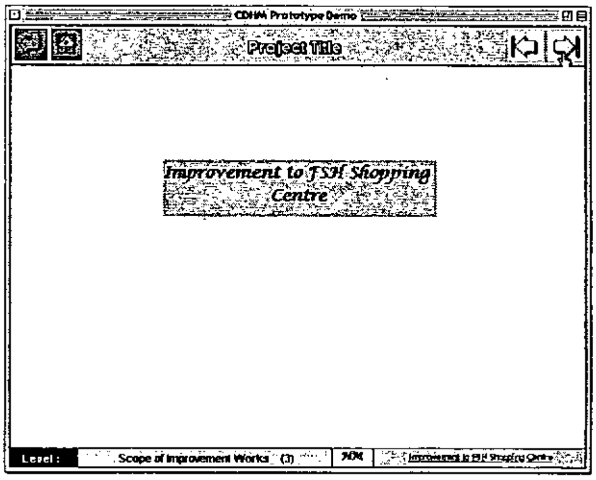
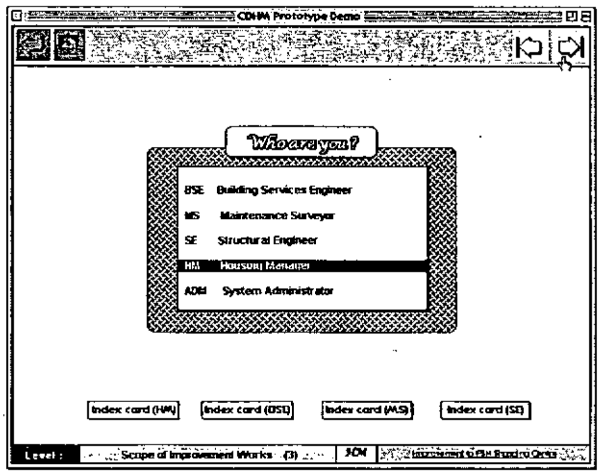
CDHM Prototype Demo
Transformer House I
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Two locations for siting transformer house are proposed:
1.
Storeroom 1, G/F, Shin Lun House (approximately 45 sq m).
2.
Adjacent to RCP underneath the cooked food stall (approximately 99 sq m).
Remark:
Link to:
This Card
This Stack
Cancel
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed?
Index card
Change level
Set User Profile
Level:
Scope of Improvement Works (3)

HM

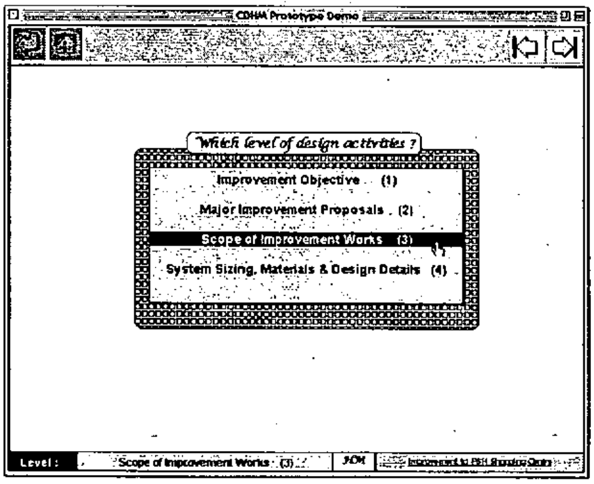


Remarks: The updated CDHM is sent to BSE and MS for agreement. However, before comments are received, HM has changed his mind and prepares another proposal.

ROUND 2: HM to present his second set of proposals

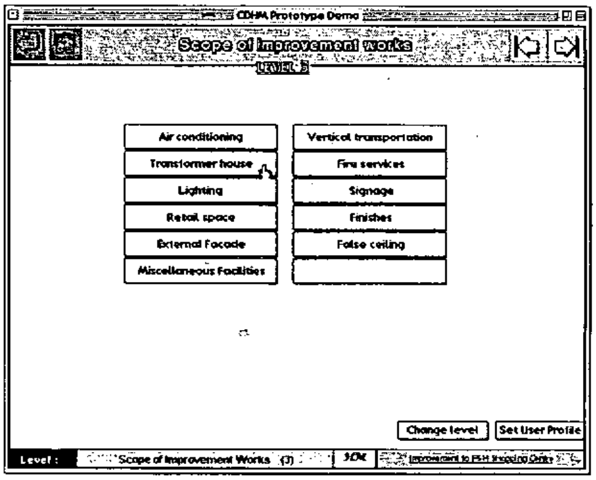
Action Member	CDHM Display Sequence
HM	
HM	

HM



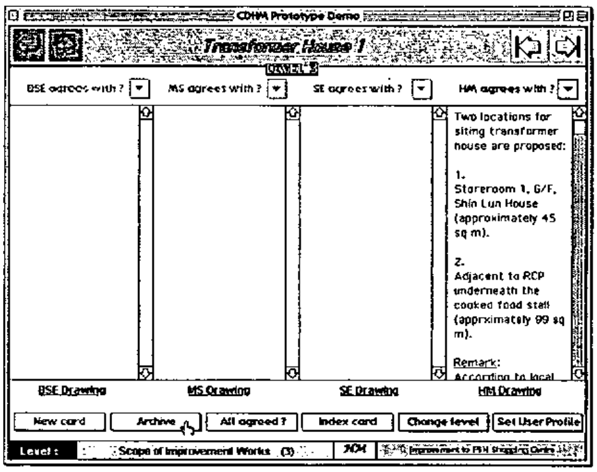
CDHM Prototype Demo
Which level of design activities ?
Improvement Objective (1)
Major Improvement Proposals (2)
Scope of Improvement Works (3)
System Sizing, Materials & Design Details (4)
Level :
Scope of Improvement Works (3)

HM



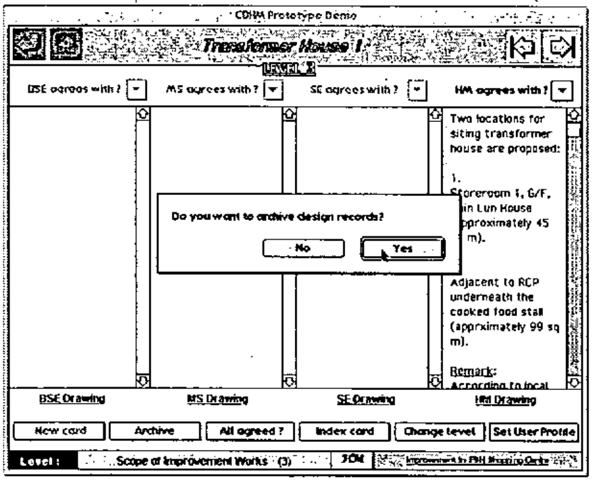
CDHM Prototype Demo
Scope of improvement works
Air conditioning
Vertical transportation
Transformer house
Fire services
Lighting
Signage
Retail space
Finishes
External Facade
False ceiling
Miscellaneous Facilities
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

HM

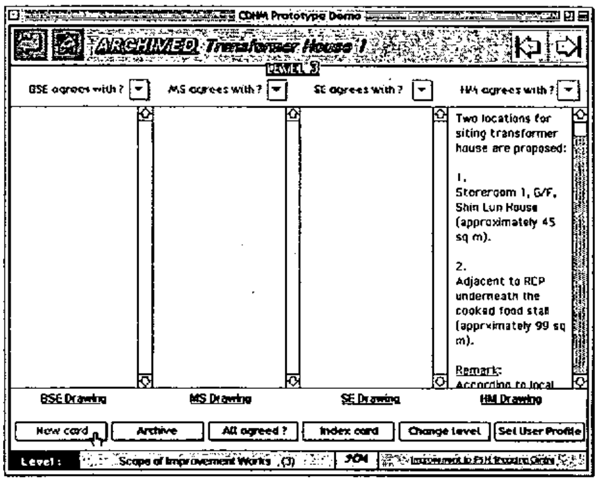


CDHM Prototype Demo
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Two locations for siting transformer house are proposed:
1.
Storeroom 1, G/F, Shin Lun House (approximately 45 sq m).
2.
Adjacent to RCP underneath the cooked food stall (apprximately 99 sq m).
Remark:
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

HM

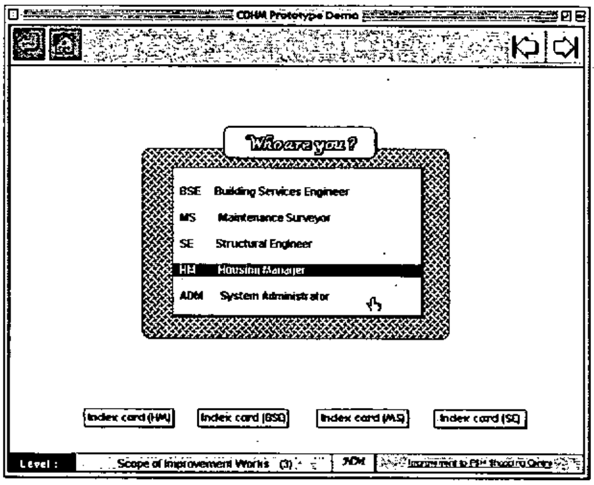


HM

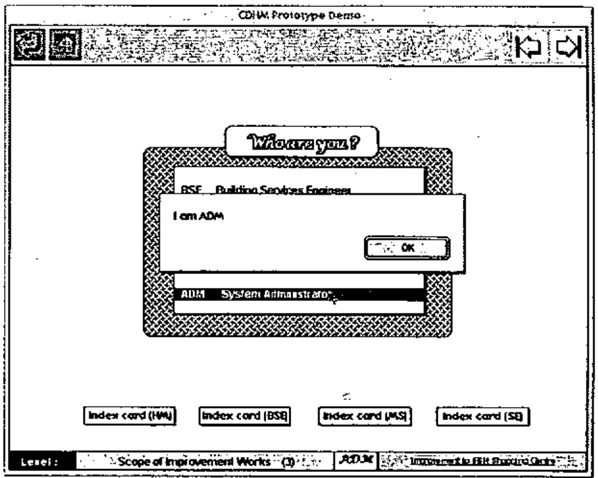


<u>Remarks</u>: **The collaboration matrix "Transformer House 1" is archived. A new collaboration matrix therefore has to be created. The CDHM is passed to ADM who is the only member authorized to create a new collaboration matrix, in this case "Transformer House 2".**

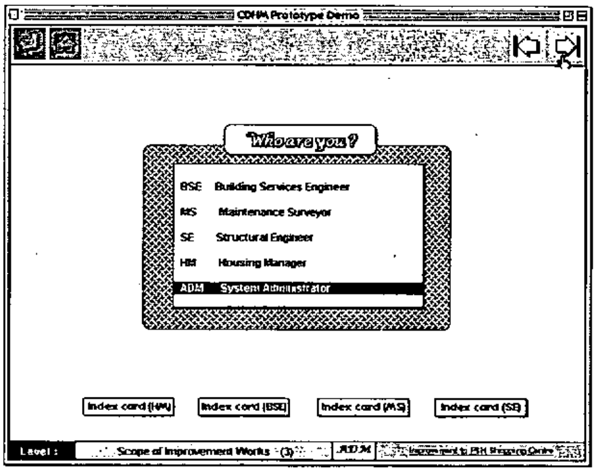
ADM


CDHM Prototype Demo
Who are you?
BSE Building Services Engineer
MS Maintenance Surveyor
SE Structural Engineer
HM Housing Manager
ADM System Administrator
Index card (HM)
Index card (BSE)
Index card (MS)
Index card (SE)
Level:
Scope of Improvement Works (3)
ADM

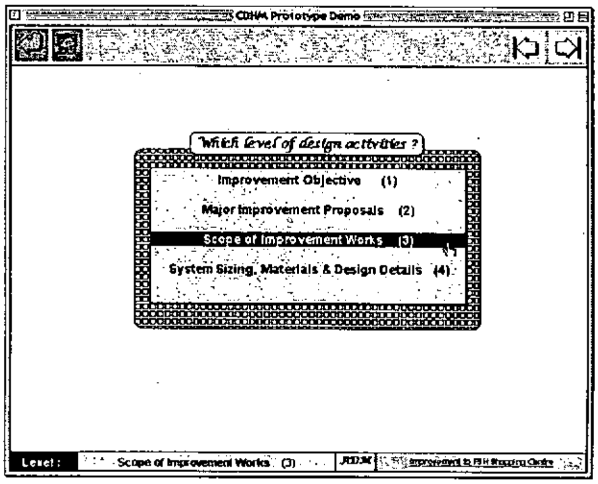
ADM


CDHM Prototype Demo
Who are you?
I am ADM
OK
ADM System Administrator
Index card (HM)
Index card (BSE)
Index card (MS)
Index card (SE)
Level:
Scope of Improvement Works (3)
ADM

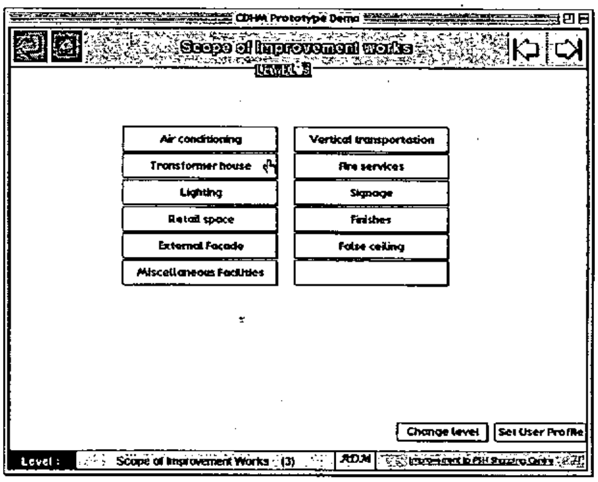
ADM


CDHM Prototype Demo
Who are you?
BSE Building Services Engineer
MS Maintenance Surveyor
SE Structural Engineer
HM Housing Manager
ADM System Administrator
Index card (HM)
Index card (BSE)
Index card (MS)
Index card (SE)
Level:
Scope of Improvement Works (3)
ADM

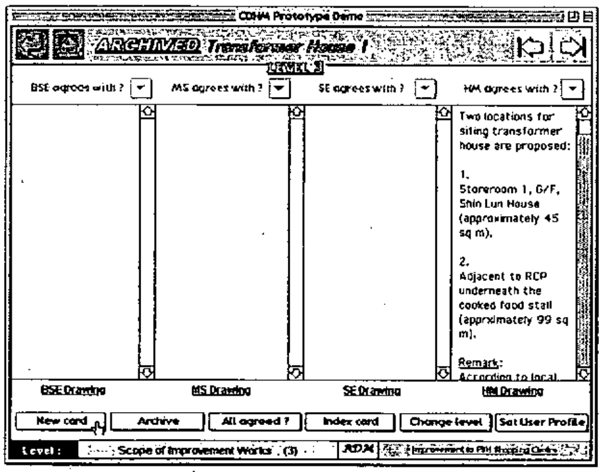
ADM


CDHM Prototype Demo
Which level of design activities ?
Improvement Objective (1)
Major Improvement Proposals (2)
Scope of Improvement Works (3)
System Sizing, Materials & Design Details (4)
Level :
Scope of Improvement Works (3)
ADM

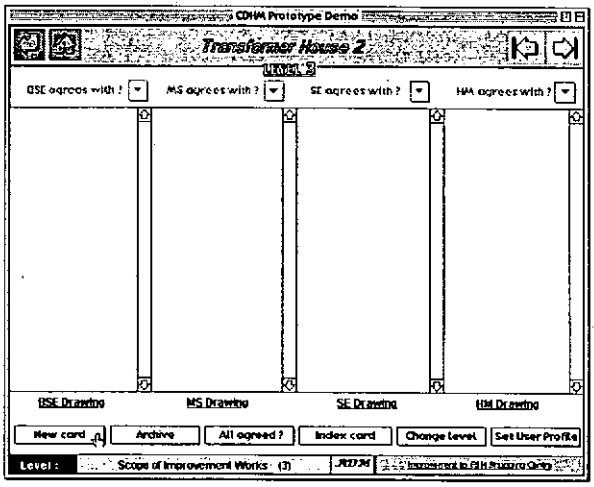
ADM


CDHM Prototype Demo
Scope of Improvement works
LEVEL 3
Air conditioning
Vertical transportation
Transformer house
Fire services
Lighting
Signage
Retail space
Finishes
External Facade
False ceiling
Miscellaneous Facilities
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
ADM

ADM

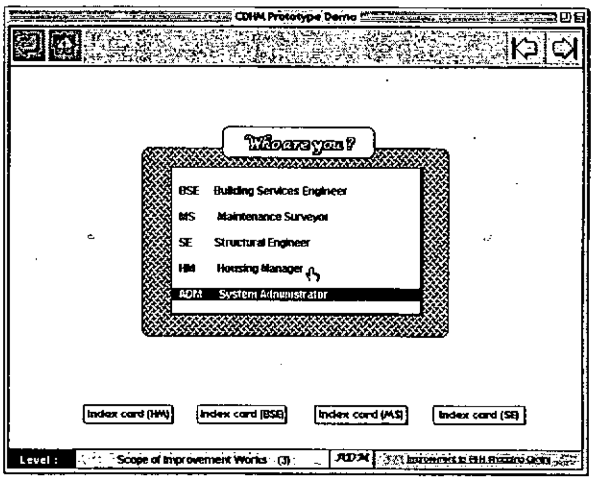

CDHM Prototype Demo
ARCHIVED Transformer House I
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Two locations for siting transformer house are proposed:
1.
Storeroom 1, G/F, Shin Lun House (approximately 45 sq m).
2.
Adjacent to RCP underneath the cooked food stall (approximately 99 sq m).
Remark:
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
ADM

ADM

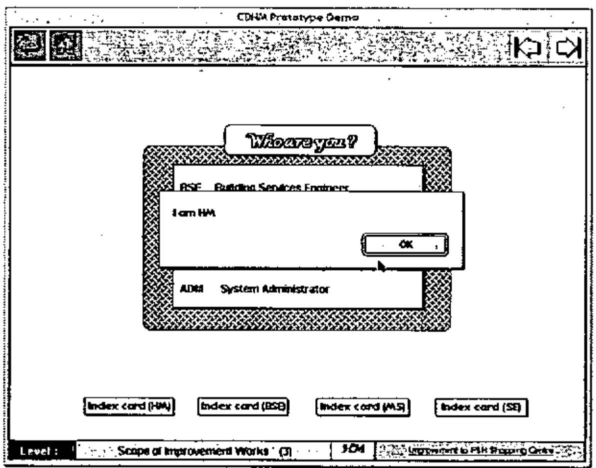


Remarks: Now ADM has created a new collaboration matrix (i.e. "Transformer House 2), which is then sent back to HM.

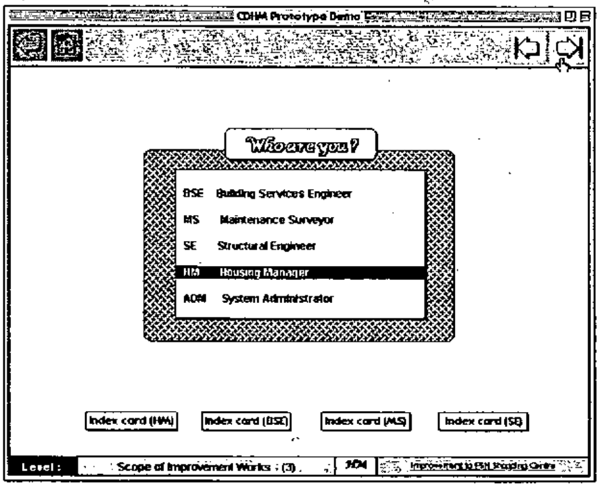
HM



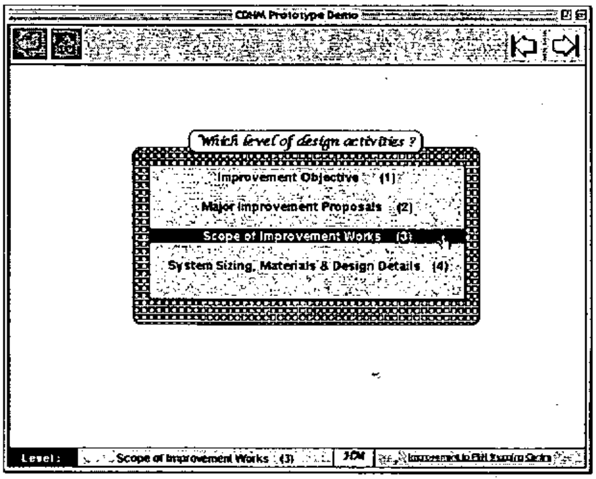
HM



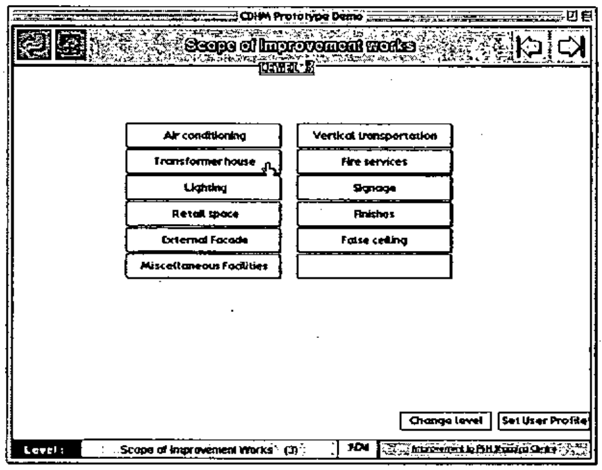
HM


CDHM Prototype Demo
BSE Building Services Engineer
MS Maintenance Surveyor
SE Structural Engineer
HM Housing Manager
ADM System Administrator
Index card (HM)
Index card (BSE)
Index card (MS)
Index card (SE)
Level :
Scope of Improvement Works : (3)

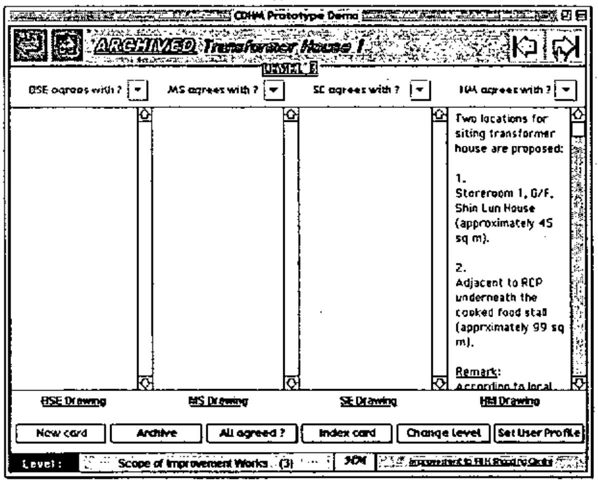
HM


CDHM Prototype Demo
Which level of design activities ?
Improvement Objective (1)
Major Improvement Proposals (2)
Scope of Improvement Works (3)
System Sizing, Materials & Design Details (4)
Level :
Scope of Improvement Works (3)

HM

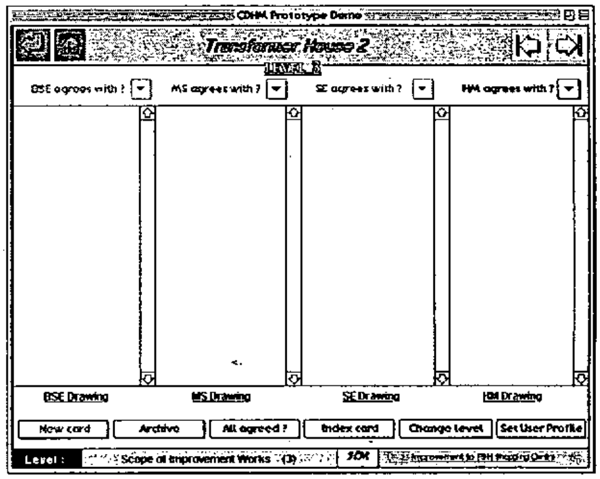

CDHM Prototype Demo
Scope of Improvement works
Air conditioning
Vertical transportation
Transformer house
Fire services
Lighting
Signage
Retail space
Finishes
External Facade
False ceiling
Miscellaneous Facilities
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

HM



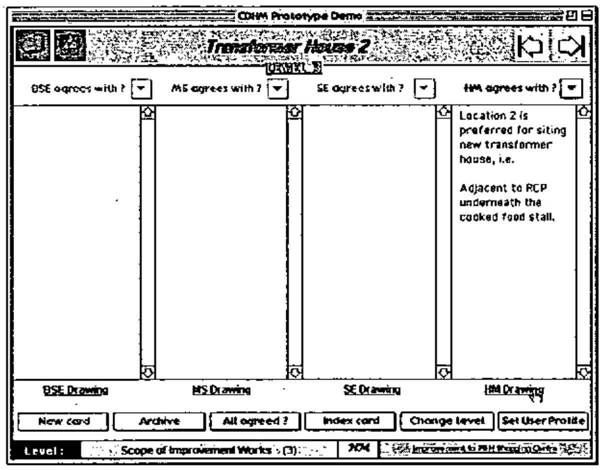
CDHM Prototype Demo
ARCHIVED Transformer House 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Two locations for siting transformer house are proposed:
1. Storeroom 1, G/F, Shin Lun House (approximately 45 sq m).
2. Adjacent to RCP underneath the cooked food stall (apprximately 99 sq m).
Remark:
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

HM



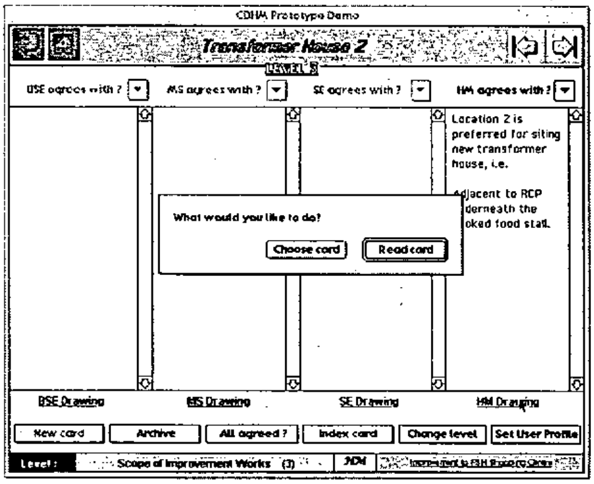
CDHM Prototype Demo
Transformer House 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

HM

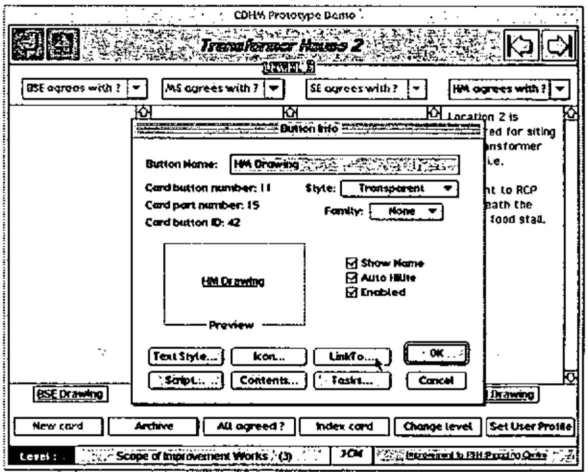


CDHM Prototype Demo
Transformer House 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

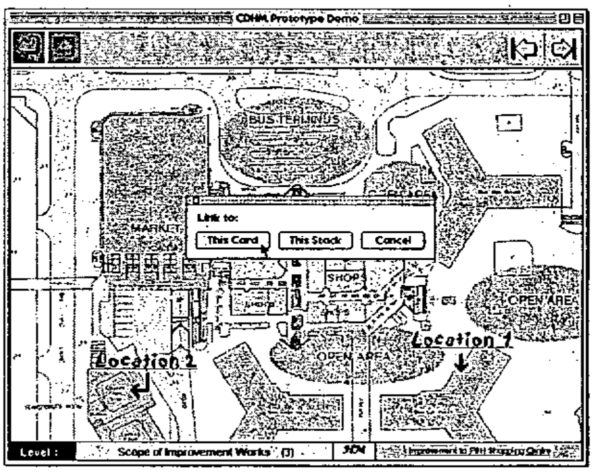
HM


CDHM Prototype Demo
Transformer House 2
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
What would you like to do?
Choose card
Read card
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

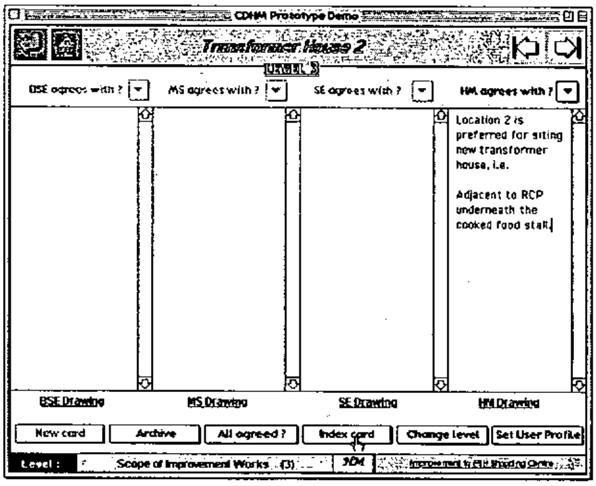
HM


CDHM Prototype Demo
Transformer House 2
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Button Info
Button Name: HM Drawing
Card button number: 11
Card part number: 15
Card button ID: 42
Style: Transparent
Family: None
HM Drawing
Preview
Show Name
Auto Hilite
Enabled
Text Style...
Icon...
LinkTo...
OK
Script...
Contents...
Tasks...
Cancel
BSE Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)

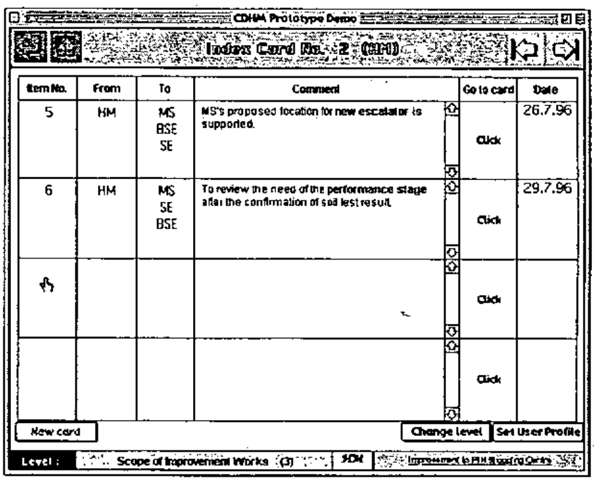
HM


CDHM Prototype Demo
BUS TERMINUS
MARKET
Link to:
This Card
This Stack
Cancel
SHOPS
OPEN AREA
Location 1
Location 2
Level :
Scope of Improvement Works (3)

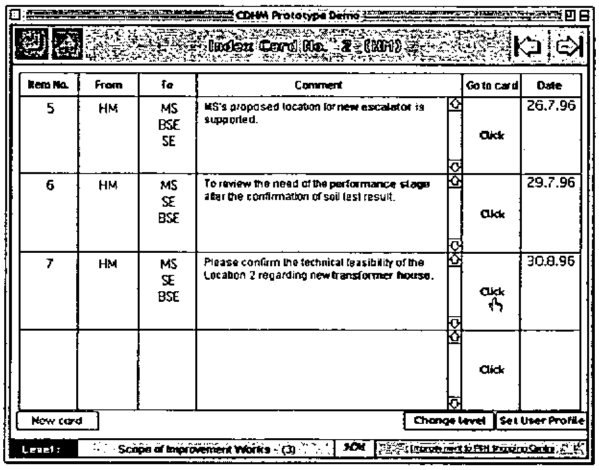
HM


CDHM Prototype Demo
Transformer House 2
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works - (3)

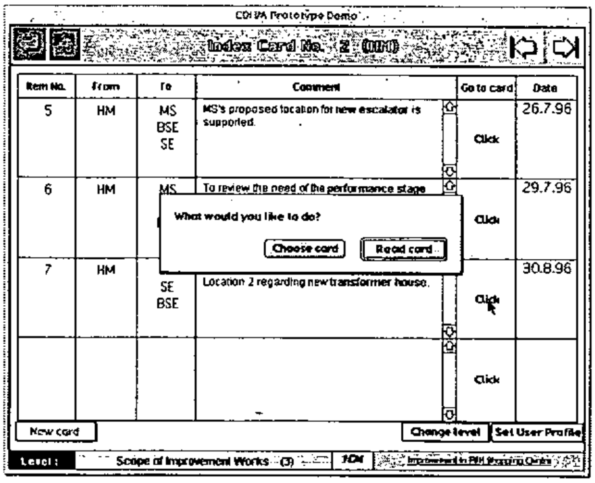
HM


CDHM Prototype Demo
Index Card No. 2 (HM)
Item No.
From
To
Comment
Go to card
Date
5
HM
MS
BSE
SE
MS's proposed location for new escalator is supported.
Click
26.7.96
6
HM
MS
SE
BSE
To review the need of the performance stage after the confirmation of soil test result.
Click
29.7.96
Click
Click
New card
Change level
Set User Profile
Level :
Scope of Improvement Works - (3)

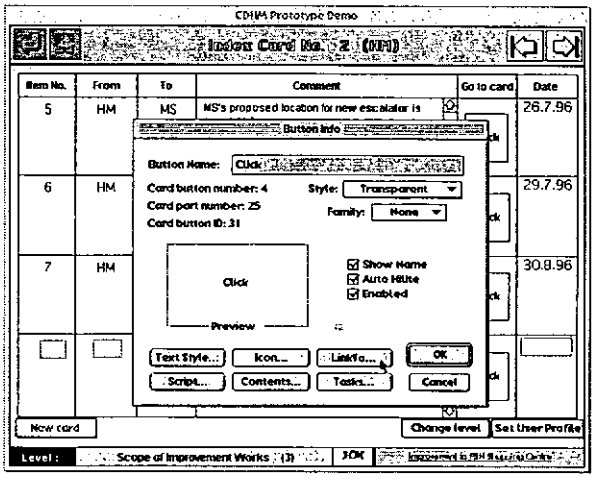
HM


CDHM Prototype Demo
Index Card No. 2 (HM)
Item No.
From
To
Comment
Go to card
Date
5
HM
MS
BSE
SE
MS's proposed location for new escalator is supported.
Click
26.7.96
6
HM
MS
SE
BSE
To review the need of the performance stage after the confirmation of soil test result.
Click
29.7.96
7
HM
MS
SE
BSE
Please confirm the technical feasibility of the Location 2 regarding new transformer house.
Click
30.8.96
Click
New card
Change level
Set User Profile
Level :
Scope of Improvement Works - (3)

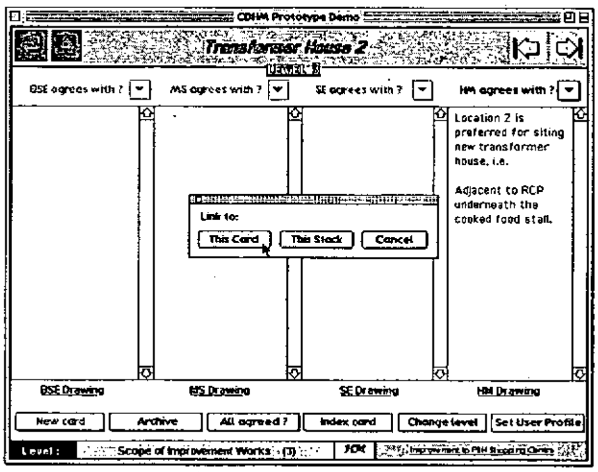
HM


CDHM Prototype Demo
Index Card No. 2 (HM)
Item No.
From
To
Comment
Go to card
Date
5
HM
MS
BSE
SE
MS's proposed location for new escalator is supported.
Click
26.7.96
6
HM
To review the need of the performance stage
What would you like to do?
Choose card
Read card
29.7.96
7
HM
SE
BSE
Location 2 regarding new transformer house.
30.8.96
New card
Change level
Set User Profile
Level:
Scope of Improvement Works (3)

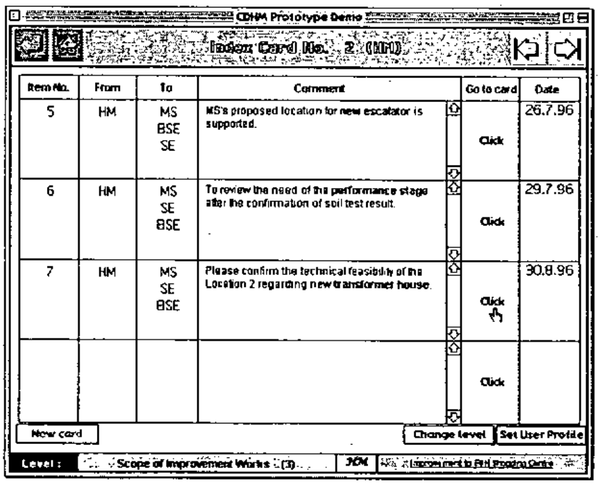
HM


CDHM Prototype Demo
Index Card No. 2 (HM)
Button Info
Button Name:
Card button number: 4
Card part number: 25
Card button ID: 31
Style: Transparent
Family: None
Show Name
Auto Hilite
Enabled
Preview
Text Style...
Icon...
LinkTo...
OK
Script...
Contents...
Tasks...
Cancel
New card
Change level
Set User Profile
Level:
Scope of Improvement Works (3)

HM

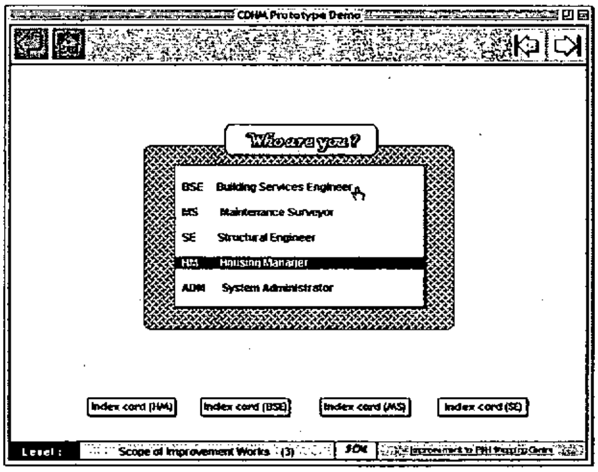

CDHM Prototype Demo
Transformer House 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Link to:
This Card
This Stack
Cancel
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level:
Scope of Improvement Works (3)

HM

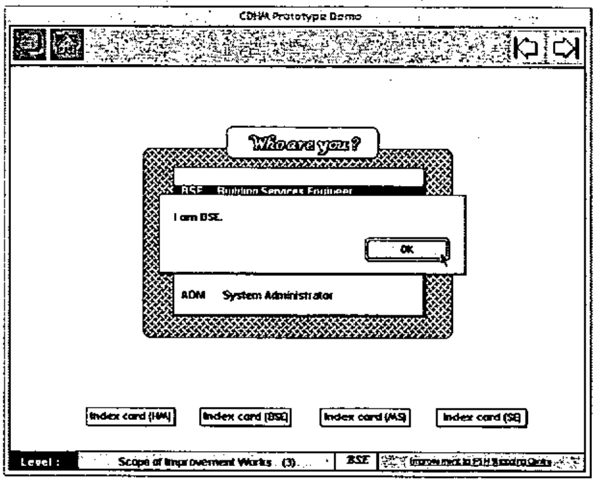


<u>Remarks</u>: **The revised CDHM is sent to BSE, MS and SE for comments/ agreement.**

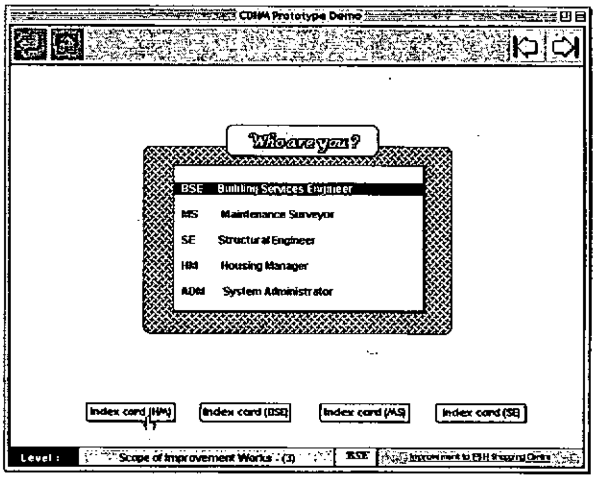
ROUND 3: Feedbacks from BSE, MS and SE.

Action Member	CDHM Display Sequence
BSE	
BSE	

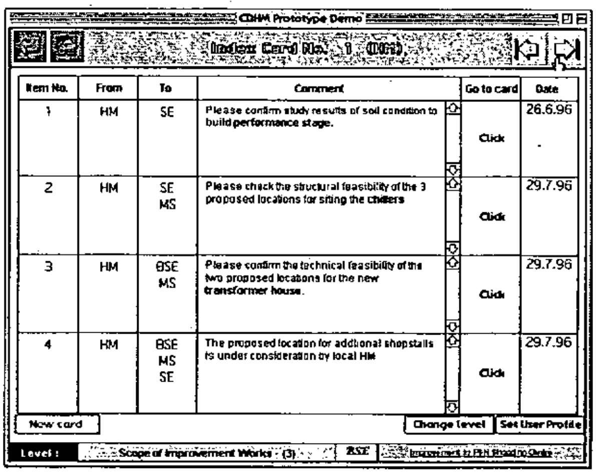
BSE


CDHM Prototype Demo
Who are you?
I am BSE.
OK
ADM System Administrator
Index card (HM)
Index card (BSE)
Index card (MS)
Index card (SE)
Level :
Scope of Improvement Works (3)
BSE

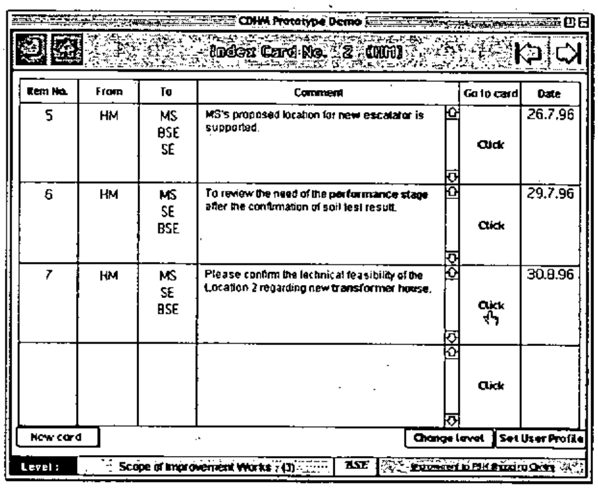
BSE


CDHM Prototype Demo
Who are you?
BSE Building Services Engineer
MS Maintenance Surveyor
SE Structural Engineer
HM Housing Manager
ADM System Administrator
Index card (HM)
Index card (BSE)
Index card (MS)
Index card (SE)
Level :
Scope of Improvement Works (3)
BSE

BSE

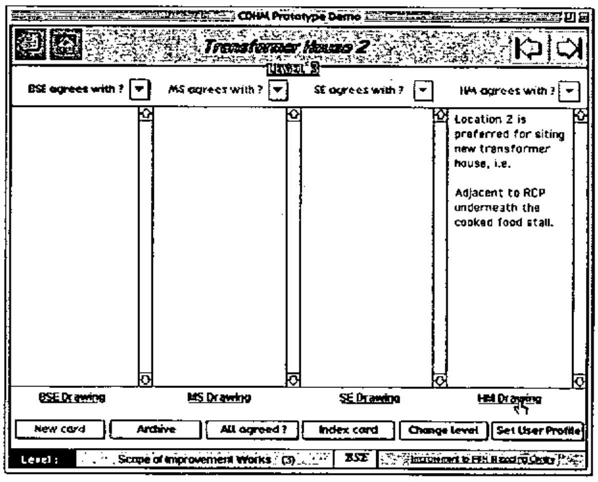

CDHM Prototype Demo
Item No.
From
To
Comment
Go to card
Date
1
HM
SE
Please confirm study results of soil condition to build performance stage.
Click
26.6.96
2
HM
SE MS
Please check the structural feasibility of the 3 proposed locations for siting the chillers
Click
29.7.96
3
HM
BSE MS
Please confirm the technical feasibility of the two proposed locations for the new transformer house.
Click
29.7.96
4
HM
BSE MS SE
The proposed location for additional shopstalls is under consideration by local HM
Click
29.7.96
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

BSE



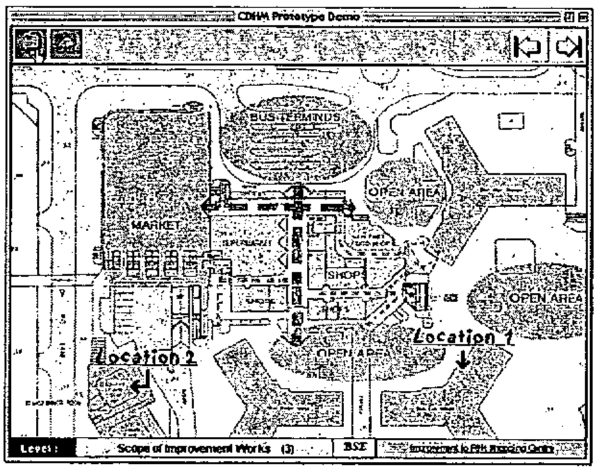
CDHM Prototype Demo
Index Card No. 2 (HM)
Item No.
From
To
Comment
Go to card
Date
5
HM
MS
BSE
SE
MS's proposed location for new escalator is supported.
Click
26.7.96
6
HM
MS
SE
BSE
To review the need of the performance stage after the confirmation of soil test result.
Click
29.7.96
7
HM
MS
SE
BSE
Please confirm the technical feasibility of the Location 2 regarding new transformer house.
Click
30.8.96
Click
New card
Change level
Set User Profile
Level :
Scope of Improvement Works : (3)
BSE

BSE



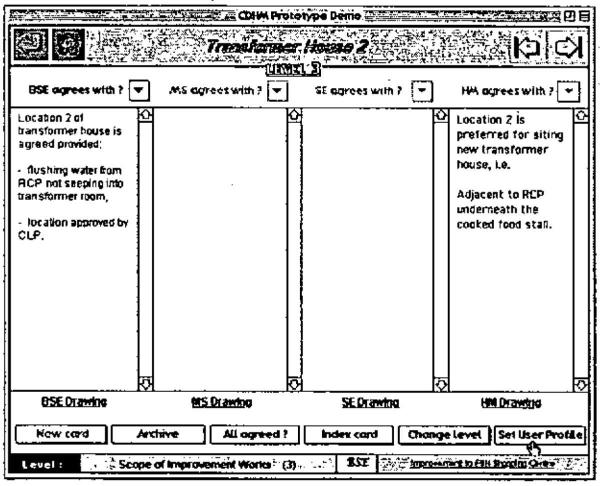
CDHM Prototype Demo
Transformer House 2
Level 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works : (3)
BSE

BSE



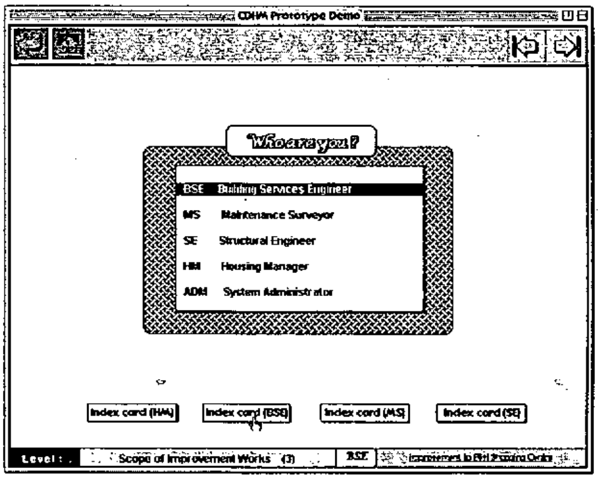
CDHM Prototype Demo
BUS TERMINUS
OPEN AREA
MARKET
SHOP
OPEN AREA
Location 1
Location 2
Level :
Scope of Improvement Works (3)
BSE

BSE



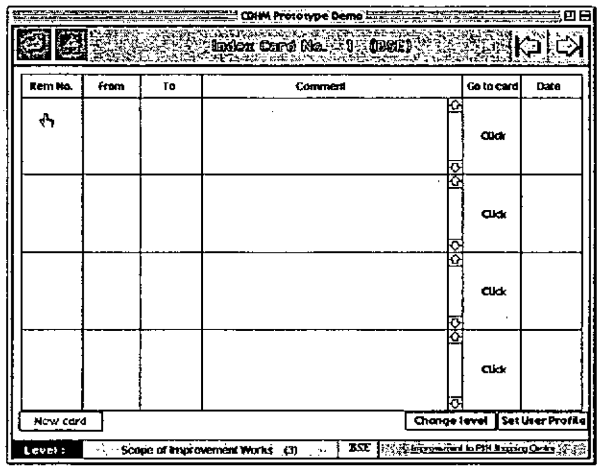
CDHM Prototype Demo
Transformer House 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 of transformer house is agreed provided:
- flushing water from RCP not seeping into transformer room,
- location approved by CLP.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change Level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

BSE



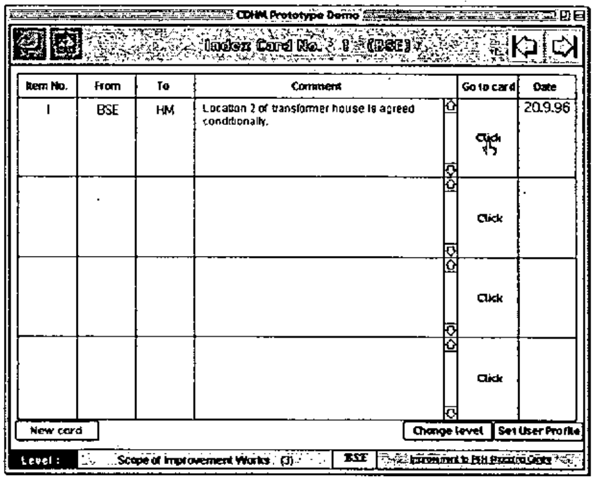
CDHM Prototype Demo
Who are you?
BSE Building Services Engineer
MS Maintenance Surveyor
SE Structural Engineer
HM Housing Manager
ADM System Administrator
Index card (HM)
Index card (BSE)
Index card (MS)
Index card (SE)
Level :
Scope of Improvement Works (3)
BSE

BSE

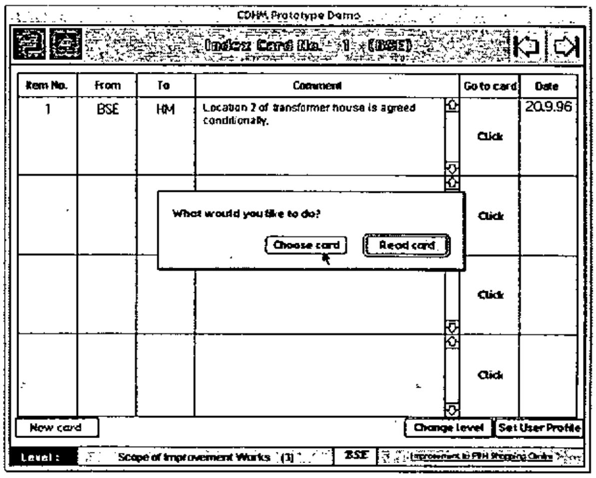


CDHM Prototype Demo
Item No.
From
To
Comment
Go to card
Date
Click
Click
Click
Click
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

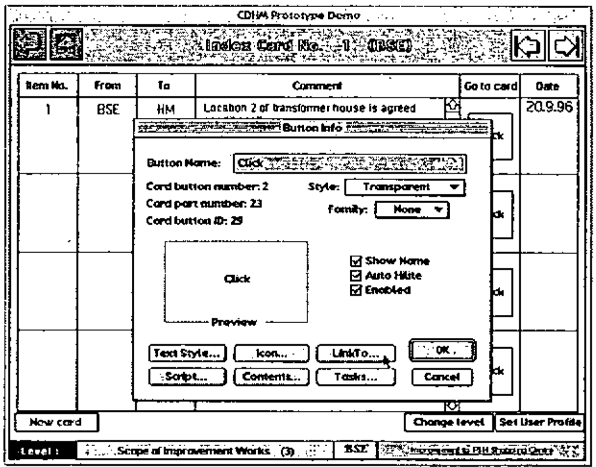
BSE


CDHM Prototype Demo
Index Card No. 1 (BSE)
Item No.
From
To
Comment
Go to card
Date
1
BSE
HM
Location 2 of transformer house is agreed conditionally.
Click
20.9.96
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

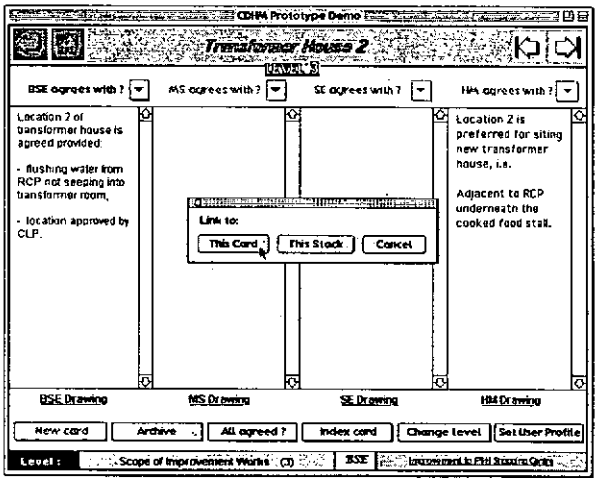
BSE


CDHM Prototype Demo
Index Card No. 1 (BSE)
Item No.
From
To
Comment
Go to card
Date
1
BSE
HM
Location 2 of transformer house is agreed conditionally.
Click
20.9.96
What would you like to do?
Choose card
Read card
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

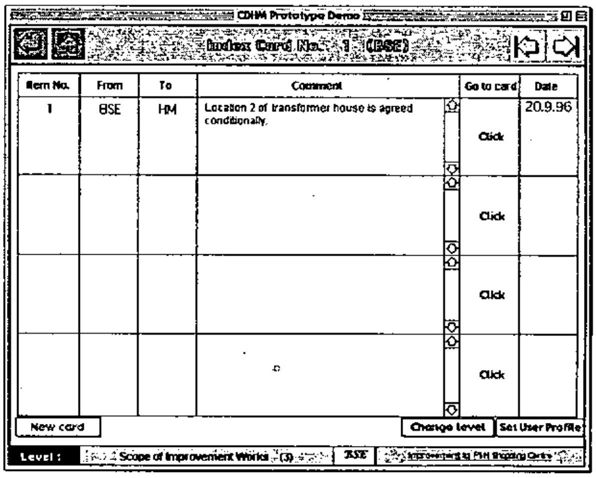
BSE


CDHM Prototype Demo
Index Card No. 1 (BSE)
Item No.
From
To
Comment
Go to card
Date
1
BSE
HM
Location 2 of transformer house is agreed
20.9.96
Button Info
Button Name:
Click
Card button number: 2
Style:
Transparent
Card part number: 23
Family:
None
Card button ID: 29
Click
Preview
Show Name
Auto Hilite
Enabled
Text Style...
Icon...
LinkTo...
OK
Script...
Contents...
Tasks...
Cancel
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

BSE

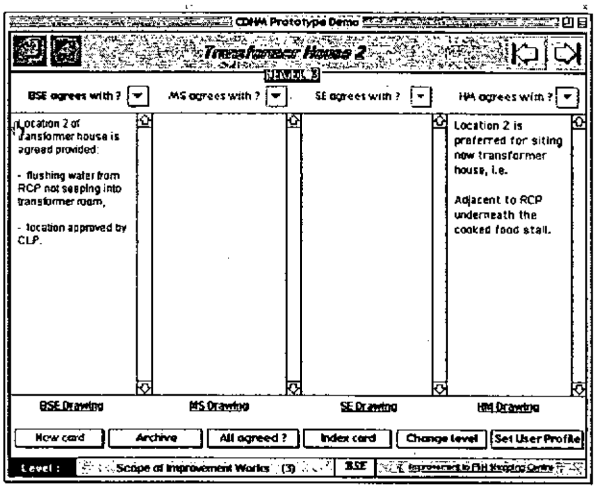


BSE

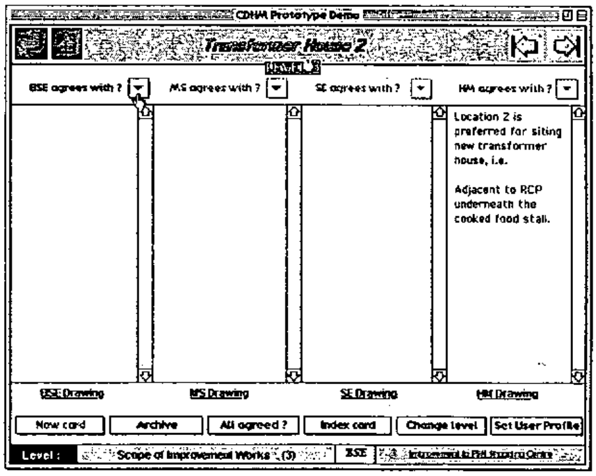


<u>Remarks</u>: BSE has agreed conditionally with Location 2. It is anticipated that these conditions can be fulfilled in due course. Therefore BSE indicates his agreement. (As the CDHM Display Sequence of subsequent navigation is almost identical with the first part of ROUND 3, the following presentation begins at "Transformer House 2" of Level 3.)

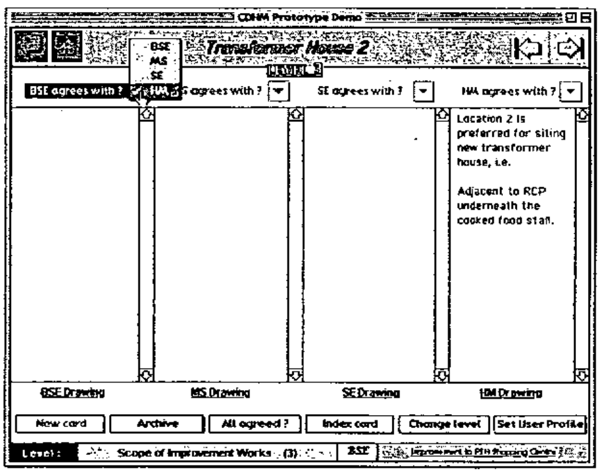
BSE


CDHM Prototype Demo
Transformer House 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 of transformer house is agreed provided:
- flushing water from RCP not seeping into transformer room,
- location approved by CLP.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

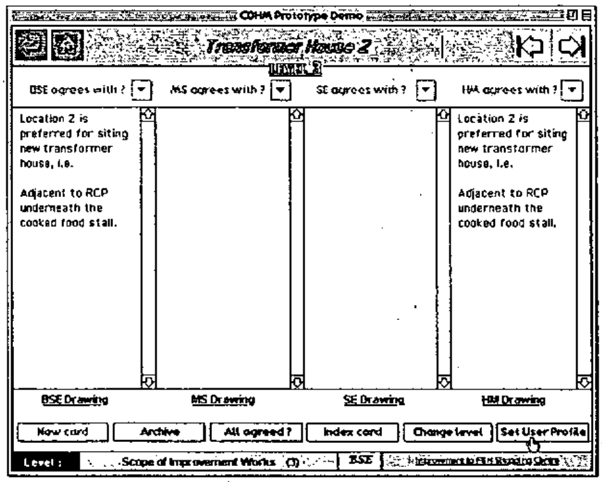
BSE


CDHM Prototype Demo
Transformer House 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

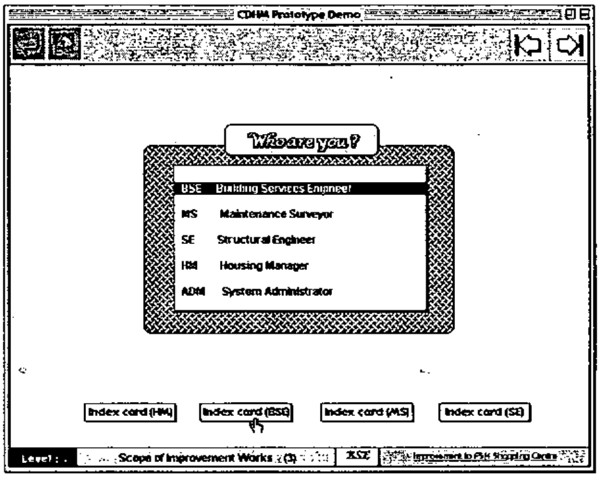
BSE


CDHM Prototype Demo
Transformer House 2
BSE
MS
SE
HM
BSE agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

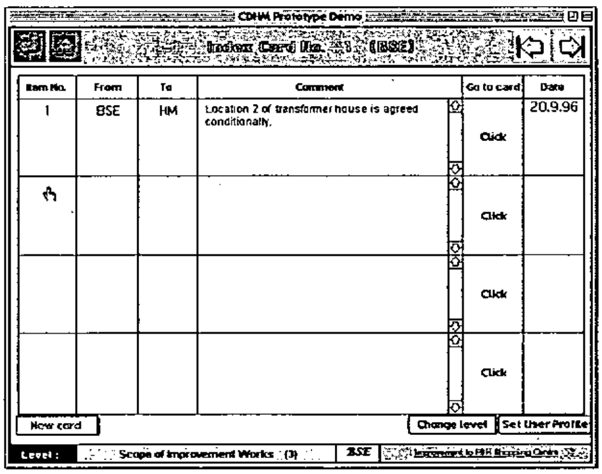
BSE


CDHM Prototype Demo
Transformer House 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

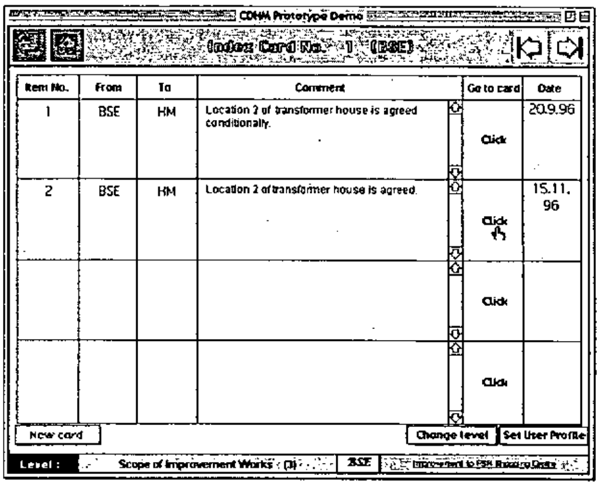
BSE


CDHM Prototype Demo
Who are you?
BSE Building Services Engineer
MS Maintenance Surveyor
SE Structural Engineer
HM Housing Manager
ADM System Administrator
Index card (HM)
Index card (BSE)
Index card (MS)
Index card (SE)
Level :
Scope of Improvement Works (3)
BSE

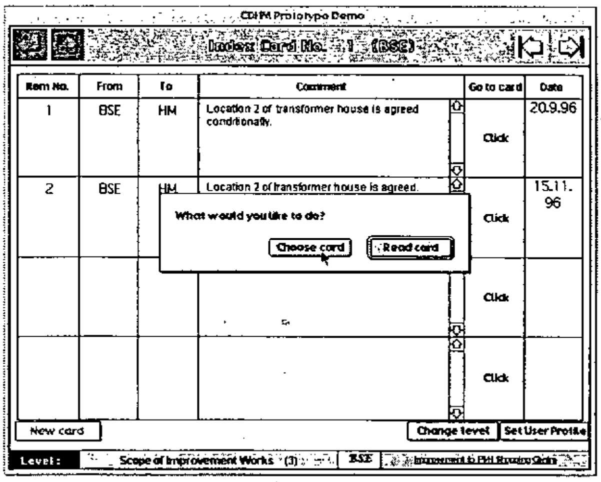
BSE


CDHM Prototype Demo
Index Card No. 1 (BSE)
Item No.
From
To
Comment
Go to card
Date
1
BSE
HM
Location 2 of transformer house is agreed conditionally.
Click
20.9.96
Click
Click
Click
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

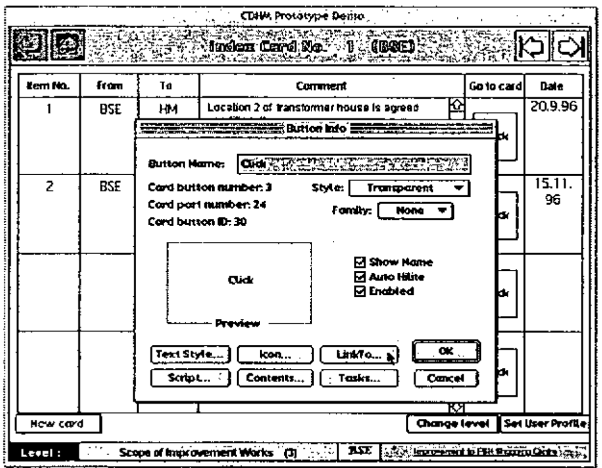
BSE


CDHM Prototype Demo
Index Card No. 1 (BSE)
Item No.
From
To
Comment
Go to card
Date
1
BSE
HM
Location 2 of transformer house is agreed conditionally.
Click
20.9.96
2
BSE
HM
Location 2 of transformer house is agreed.
Click
15.11.96
Click
Click
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

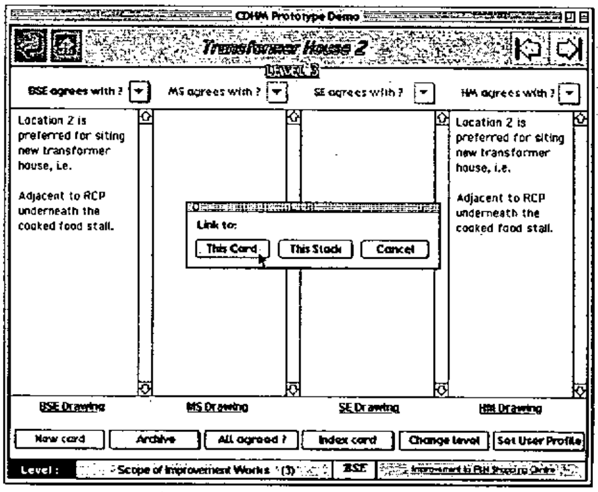
BSE


CDHM Prototype Demo
Index Card No. 1 (BSE)
Item No.
From
To
Comment
Go to card
Date
1
BSE
HM
Location 2 of transformer house is agreed conditionally.
Click
20.9.96
2
BSE
HM
Location 2 of transformer house is agreed.
15.11.96
What would you like to do?
Choose card
Read card
Click
Click
Click
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

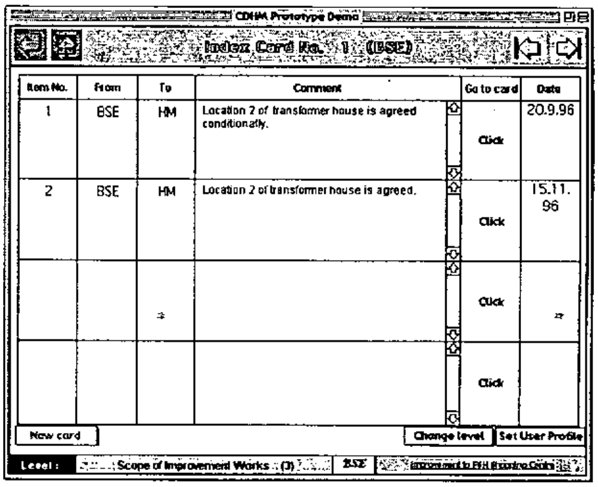
BSE


CDHM Prototype Demo
Index Card No. 1 (BSE)
Item No.
From
To
Comment
Go to card
Date
1
BSE
HM
Location 2 of transformer house is agreed
20.9.96
2
BSE
15.11.96
Button Info
Button Name:
Click
Card button number: 3
Card part number: 24
Card button ID: 30
Style:
Transparent
Family:
None
Click
Preview
Show Name
Auto Hilite
Enabled
Text Style...
Icon...
LinkTo...
OK
Script...
Contents...
Tasks...
Cancel
New card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

BSE

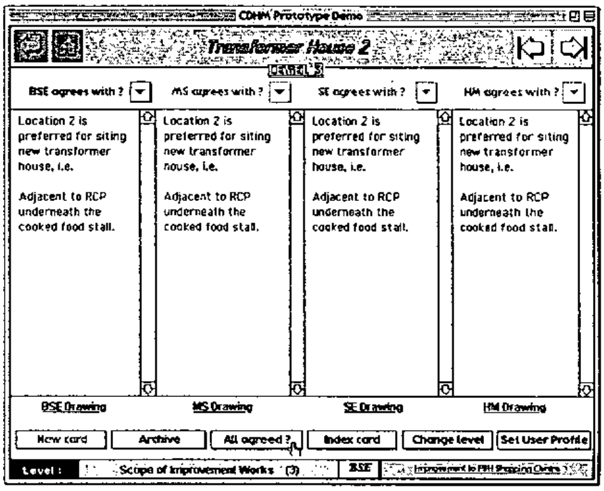


BSE



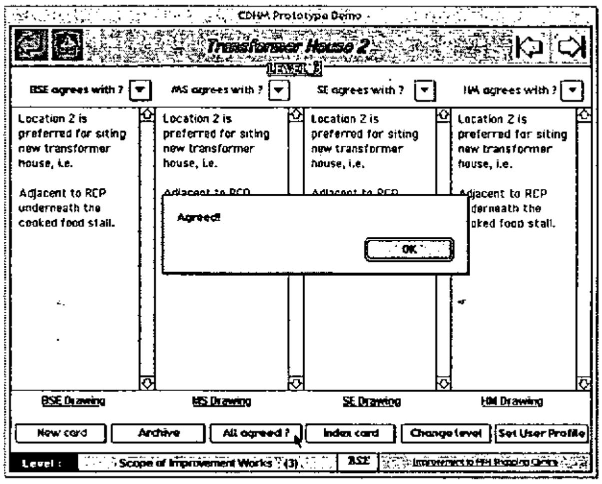
<u>Remarks</u>: **There is no major criticism from either the MS or the SE. They input their agreement into CDHM according to a navigation path that is exactly the same as that of BSE except with a different Identity Field. The result is an "Agreed" collaboration matrix as follows.**

BSE



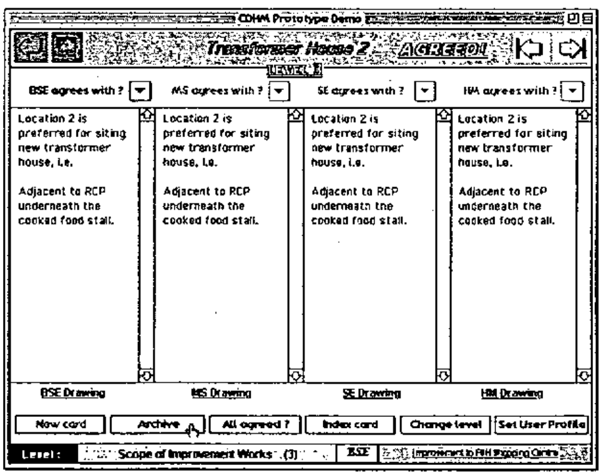
CDHM Prototype Demo
Transformer House 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

BSE



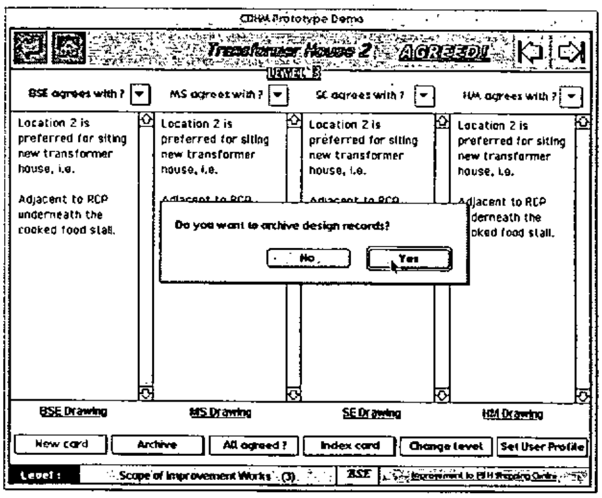
CDHM Prototype Demo
Transformer House 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Agreed!
OK
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

BSE

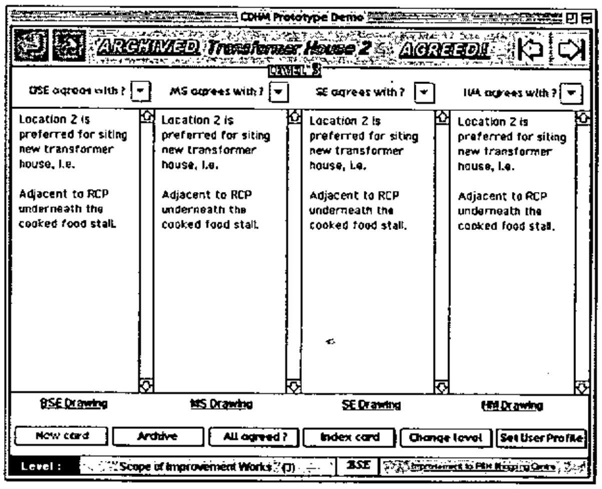


CDHM Prototype Demo
Transformer House 2
AGREED!
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

BSE


CDHM Prototype Demo
Transformer House 2
AGREED!
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Do you want to archive design records?
No
Yes
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

BSE


CDHM Prototype Demo
ARCHIVED
Transformer House 2
AGREED!
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Scope of Improvement Works (3)
BSE

5.3.2 Observation and comments

The demonstration has been carried out using the prototype CDHM that covers design activities from the beginning of the feasibility study up to the completion of the first draft of the design brief. It is successful in terms of adequacy as well as effectiveness in capturing and representing all key project information in relation to the development of a client's brief. First, the concurrency control mechanism has been shown to be viable through the construction of CDHM. Second, the performance of the control of a "no agreement" situation is satisfactory. This is substantiated by the statistics of the CDHM that have been "run" using design information of a real refurbishment project of a shopping centre, Figure 46.

	Collaboration Matrices **created**	Collaboration Matrices **utilized** (with input of project information)	Collaboration Matrices **"Agreed"**
Level 1	1	1	-
Level 2	22	19	10
Level 3	17	11	4
Level 4	11	1	-
Total	**51**	**32**	**14**

Figure 46. Statistics of "running" CDHM.

Figure 46 indicates that over 40% of the "utilized" collaboration matrices can be concluded and agreed to by all PT members. The figures also confirm that the proposed measures for controlling the "no agreement" situation is statistically at least 40% effective. The effectiveness can also be assessed from another perspective. For example, the resultant

CDHM can be compared with the subsequent draft design brief that has been (previously) documented in the paper system. In principle all improvement proposals given in the design brief should coincide with those "Agreed" collaboration matrices of CDHM. Naturally there are discrepancies between these two different groups of information which have been organized through different media and methodologies. The design brief contains 25 improvement items in which 6 items are not directly included in the development process of CDHM because these are standard information from the perspective of "Basic Information Model" (Figure 5). A typical example is "the shops shall be provided with basic facilities according to the Estate Facilities design Guide-Commercial Centres of the Housing Authority, licensing and environmental protection regulations". Consequently, the design brief essentially has 19 improvement items. The results of the comparison are shown in Appendix 4 and are summarized below, Figure 47.

Status of Improvement Item	Nos.
Improvement items with corresponding "Agreed" collaboration matrices	**15**
Improvement items with corresponding collaboration matrices with no agreement	**2**
Improvement items without collaboration matrices	**2**
Improvement items requiring no collaboration matrices (standard information)	**6**
Total	**25**

Figure 47. Comparison of design brief against CDHM.

By neglecting the standard information items, CDHM has captured almost 80% (i.e. 15 items out of 19 items) of the design brief on the understanding that "Agreed" collaboration matrices essentially represent the design brief. Furthermore, there exists at least one

"Agreed" collaboration matrix that cannot match any improvement item of the design brief and which is obviously an overlooked item. In other words, CDHM is more reliable in ensuring all "Agreed" items will be included in the design brief.

It has also been observed that there are cases where a member prefers to impose conditions on his improvement proposal agreement. Currently no facility exists in CDHM to cope directly with such a situation. Alternatively, the collaboration matrix that represents this improvement proposal could be archived while further negotiation of the proposal might continue by starting a new collaboration matrix. This process might carry on until an "agreed" collaboration matrix is obtained.

Regarding the effectiveness of managing design changes, it can be shown that it only takes a few mouse clicks to reach the target item, notwithstanding that there are over 50 collaboration matrices in CDHM. It may be argued that the retrieving of a specific design item can be carried out more directly by means of keyword search. Again, it can be shown that as far as authoring is concerned, keyword search is less productive than navigating in accordance with the orientation and guidance provided by the CDHM structure. For example, if the term "transformer house" is searched, the results return 11 nos. (implying a minimum of 11 mouse clicks) to locate all items, while it only takes three to four mouse clicks to reach exactly the item that contains "transformer house" by following the CDHM structure. The size of CDHM (hence the nos. of collaboration matrices) grows when the design brief is further developed. The four-level architecture of CDHM has provided a relatively efficient and accurate means for retrieving archived data relating to managing design changes.

The foregoing paragraph indicates that navigation is superior to direct searching in retrieving the right item. In fact, it has been suggested that information retrieval techniques like computing precision and recall are not directly usable in the evaluation of characteristics of hypertext information retrieval system [Agosti, M., 1996]. In order to compute precision and recall one needs a collection of documents, a set of user queries and a set of documents known to be relevant for each of those queries [Smeaton, A. F., 1996]. However, the situation in CDHM is somewhat different. A major task of CDHM is to provide navigation and searching facilities to several users working in a collaborative mode within a single document, a document which could be significantly large. CDHM is virtually a "live" document, meaning it is updated continuously under a commonly accepted protocol. Obviously, the relevance of any subsequently retrieved data whose purpose is to facilitate navigation is ensured by the characteristics of the CDHM architecture. It follows that the most crucial concern of an evaluation is the validity of the CDHM architecture, which can be verified by peer review.

CHAPTER SIX

Chapter 6: Discussions and conclusions

6.1 Discussions

6.1.1 Innovation

A qualitative approach to engineering design is not common. This is particularly so at the detailed design stage where intense mathematical analysis is common. However, detailed design cannot be carried out in the absence of well-defined concepts. At the preliminary design stage these normally warrant significant collaboration and agreement from all project team members. Exchanging design information and managing design documents are the activities that form part of a collaborative design process. However, these activities alone rarely ensure meaningful communication between project team members as far as an agreement to a design concept is concerned. While the quantitative aspects of collaboration may include various countable items such as the number of documents generated and shared between the collaborating parties, design issue statistics referred to in this research project indicates that there are still many aspects of collaboration that are not readily quantified. The representation of an agreement about a design concept is a typical example. Hence the choice of a qualitative method deserves serious consideration if this portion of the design process is to be investigated.

This research project attempts to tackle this situation in an unconventional manner with respect to the current practice in HKHA. The study has gone beyond the conceptual modelling by taking an in-depth analysis of the practical sequence where the pursuit of an agreement is developed against a respective design issue. Proprietary solutions for collaborative work tend to provide a platform for collaborating parties, who are located in different parts of the world, to access and to view a drawing or a document simultaneously. As such the strength of the Internet is being harnessed in response to the need of doing business on a global scale. A solution offered by a software developer is likely to be as general as possible in order to attract more customers. However, a collaborative design process for the construction industry is so complex that the transmission of a document over the Internet is not the main concern if the contents of design activities are to be organized meaningfully. If a simple tool is adequate to meet the local needs (such as the in-house application in this research project), the procurement of a mega-scale system is not readily justified. CDHM is built using HyperCard that costs 100 US dollars for each copy and can be shared over an existing network, Intranet or Internet.

Therefore, CDHM is innovative in the sense that it provides a paradigm for collaborating project team members to anchor his /her design concept and preferences in an integrated model in contrast to the fragmented design information traditionally found in a paper-bound file system or e-mail system. There is no imminent need to provide a dedicated Intranet system because the basic Internet service is adequate. The chance of having missing links in the design development process can be minimized. Its simplicity and minimum level of intelligence allow a user to have maximum control over his/her pace in authoring and communicating with other members.

6.1.2 Open forum

The title of this research project features building services engineering system. The research itself ends up with a computer-aided system, the concept of which appears to be applicable to all disciplines of a refurbishment project. Indeed the research has been started from the perspective of a building services engineer in contemplation of a simple but essential purpose, i.e. the quest for a survival kit to enable a BSE to perform competently in response to a client's changing requirements. It can be seen from the four-level configuration of CDHM that the definitions of the sub-levels are oriented to building services engineering design in most cases. It is possible that a structural engineer may customize the CDHM by putting additional sub-levels into the model structure to suit his own purpose, such as a 'Framing Plan'. However, it is fair to ask a simple question, namely 'Is CDHM a tool for the BSE only?'

The answer is surely no. The model, although biased towards the BSE, is sufficiently robust to cope with all construction professions. For example, an air-conditioning design programme and a framing plan design programme may be integrated into one system so that any major structural openings - say to provide a passage for a large air duct - may be analyzed through the same mathematical iteration. This would not be the case in normal practice since design packages are typically developed by experts for their own field (e.g. a BSE develops a building services engineering design package) and no 'jack-of-all-trades' is competent enough to master all the knowledge within a single development.

The CDHM demonstrates that the overlapping of discipline boundaries is inevitable if a BSE is determined to collaborate with members of other disciplines. A 'vice versa' situation will occur if an MS, say, wishes to collaborate in the same manner. In other words, the CDHM is the vehicle that enables all PT members to work together in a collaborative design undertakings. CDHM provides a platform for an open forum that helps to integrate different design concepts and statements with often no expectations of a solution. In brief, CDHM is an BSE-oriented system that can be readily modified to accommodate requirements of other disciplines.

6.1.3 Flexibility and constraints

It has been stressed that providing flexibility in the user-interface is important for tackling complex problems (Section 3.6). However, CDHM has been developed to allow only four PT members to work concurrently. Thus CDHM may be said to be inflexible if the number of participating members is to be increased at any time. (The basic module of CDHM is a collaboration matrix which is essentially a four by two matrix. "Four" represents the four PT members. If this number is changed from four to five, CDHM would need to be modified, i.e. card by card.) However, the CDHM may be configured to accommodate more PT members to allow 'spare' membership for future expansion. Nevertheless, such a 'spare' provision does not enhance the flexibility of CDHM where coping with a changing design is concerned.

For a given project, the number of key parties participating in the design process should remain unchanged. Flexibility is most needed to handle a developing design proposal, i.e. the specific design requirements as defined in the Basic Information Model (Figure 5). For this reason the addition of sub-levels better facilitates this basic principle. Furthermore, it agrees with the earlier findings that a hypermedia node cannot directly emulate a "PT member" (Section 4.3). The main concern is to have adequate flexibility in representing the concepts generated by members instead of the "name" of a member.

There is another area where the aspiration for flexibility conflicts with the elements of collaboration, i.e., concurrency control. Concurrency control has been built into the system to prevent any unauthorized access and/ or change of design information. Hence it may be argued that the controlled area is inflexible since it denies access to unauthorized members. However, the "All agreed" and "Archive" buttons can be operated by any PT member. During the "Peer Review" of the evaluation, someone suggests that an "editor" may be required in order to conclude a debate over controversial issues or otherwise the story will never end. In other words, consideration has to be given to deciding whether concurrency control should be extended to these two buttons in question.

Under the current arrangement, the "All agreed?" button will not stamp any "Agreed!" to a card unless all the fields of the four PT members are the same. Therefore, indirect control already exists. On the other hand, any one can operate the "Archive" button, meaning a

BSE may archive a collaboration matrix if he does not like the idea of HM. Though the HM may have an unpleasant feeling when his proposal is archived by another member, archiving helps to record the client's brief history. Archived information (by whom and for what reason) helps the collective memory wherever a client's brief is questioned or revisited. Project team members, knowing that they can question and reject proposals, would use this facility fairly since their views remain 'open' throughout the project. The presence of this obsolete "Archived" information does no harm to the effectiveness of CDHM because it has been clearly marked with regard to identity. In summary, the level of flexibility is appropriate for the task that has been defined.

6.1.4 Industry Foundation Classes

CDHM has been targeted for users belonging to an in-house design team. Under normal circumstances, all PT members should have no difficulties in understanding each other as far as adopted terminology is concerned. For example, they have similar specifications, conditions of contracts, drawing conventions, etc. CDHM ensures a consistent description of an improvement proposal at different levels of the hypermedia model, a description that can be recognized readily by all PT members. Problems may arise though if CDHM is to be shared with outside professionals in a situation where a project is outsourced to a private architectural firm. In this instance the "in-house" language may not be fully understood by outsiders. For example, the meanings of "switch room" and "meter room" differ in the Hong Kong Housing Authority while in most private practices they mean the same. Clearly there are gaps in information sharing in the construction industry as a whole in Hong Kong. Solutions are being developed to bridge the gap with the awareness by researchers and practitioners of potential international business benefit.

Typically the Industry Foundation Classes (IFC) have been developed by the International Alliance for Interoperability (IAI) to provide a data exchange and sharing facilities for the building and construction sector of the industry [Wix, J, and Liebich, T., 1998a]. In brief, the IFC provides the framework and techniques for information exchange by describing "what" this information is and "how" it is exchanged. However, in reality construction domain knowledge lies outside the focus of the core product and process modelling activities such as IAI [Lockley, S.R. and McGregor, C.D., 1998]. Consequently, as far as CDHM is concerned, the modelling language cannot be readily formalized under the IFC framework. Nevertheless, CDHM should be IFC-proved in the long run if the scope of collaboration is extended to the private sector. However, there is little evidence to indicate that the Hong Kong Construction Industry is moving towards IFC solutions, a pivotal condition for any further investment in the development of systems similar to CDHM. Therefore, it is premature to say that CDHM should be IFC-compliant when considering the very "localized" situations for which the real benefit of IFC has yet to be demonstrated. Indeed there are comments that there is still not enough hard evidence coming from real projects to fully convince Construction Industry to continue their support for the development of IFC [Wix, J. and Liebich, T., 1998b].

6.1.5 Publications

The work of this research project was reported in three international conferences and one international journal. These conferences and journal are with vested interest in the Construction Industry except the first one which was the first paper submitted during the study period. Highlights of these papers are summarized below in a chronological order.

InterSymp-97

The first paper was submitted to the "International Conference on Systems Research, Informatics and Cybernetics" (InterSymp-97). It was presented in the Focus Symposium "Advances in Collaborative Design and Decision-Support Systems". Professor Jens Pohl who was the Focus Symposium Chair is in charge of the CAD Research Centre (CADRC) in the US. The Symposium featured various solutions to complex problems typically found in industry, commerce and government organizations. (CADRC collaborates with the US Navy for developing decision-support systems for military deployment applications.) The paper was prepared at the very early stage of the research work while CDHM was not yet developed.

The paper "Collaborative Design in Building Services Engineering" in which the concept of applying hypermedia was suggested as a way to handle the design for the refurbishment of a shopping centre under a collaborative approach. The papers of the Symposium were grouped into four sessions namely (1) Computer-Assisted Design Tools, (2) Collaborative Design Partnership, (3) Computer-Assisted Design Systems and (4) Building Simulation and Reconstruction. The paper of this research project is grouped under Session 2. The most crucial concept shared by all presenters in Session 2 was that a tool (instead of a "canned" solution) should be developed in the tackling complex problems. This symposium was one of the important milestones with regard to the progress of the research in that the cognition of the collaborative design process as a complex problem was established. It formed the basis of subsequent development work.

ECPPM'98

The second paper was presented at "The Second European Conference on Product and Process Modelling in the Building Industry" (EC-PPM'98) under the title "Hypermedia and Collaborative Design". The EC-PPM'98 brought out the European spirit in the quest for universal solution on a multi-national basis to the application of information technology in the Architecture, Engineering and Construction (AEC) industries. This was quite different from the focus of InterSymp-97. The establishment of the Industry Foundation Class (IFC) was seen as the corner stone for providing long term solutions to the interoperability problem of the AEC industry, which gave rise to the study of product and process modelling. (The IFC was widely covered in the conference.) InterSymp-97 demonstrated a problem solving approach that endeavoured to provide a flexible tool for specific problem situations typically found in the decision-making process, by tapping the power of agent-based systems. It was one of the common practices adopted by researchers in America. On the other hand, European systems stressed the strength of a common protocol or data structure that was expected to be developed through a very long term and tedious process. Under such circumstances, the proposed hypermedia model of this research may be seen as a short-term solution when contrasted with research projects related to IFC. The editor of the ECPPM'98 made a comment in the preface of the conference proceeding: "Young researchers see more dynamic research areas with short timeframes for delivery of completed systems. [Amor, R., 1998]

Subsequent to the presentation in ECPPM'98, two essential elements that determined the future direction of the research were identified. First, it was unlikely that the agent-based approach could be pursued any further as an attempt to satisfy requirements for flexibility. Second, the need for a systematic approach in building a data structure had to be further reviewed notwithstanding the pursuit for a IFC-proof system might not be entirely relevant. The second paper was presented in the Process Modelling Session.

Automation in Construction

Subsequent to the Intersymp-97 and ECPPM'98, the hypermedia approach in resolving the collaborative design process was recognized as a sensible protocol internationally as far as the handling of the design information was concerned. Nevertheless, the analysis of the design process as well as the representation of the design intent regarding the tracking of their subsequent variation had to be further elaborated. In order to verify the validity of the concepts derived from such an analysis, the results of such further work were published in the journal "Automation in Construction" (AUTCON). The title of the journal paper was "Refurbishment of building services engineering systems under a collaborative design environment", which was submitted in February 1999 and published in January 2000.

Three major concepts were elaborated in the AUTCON paper. First, the identification of primary information elements was presented as a result of an in-depth analysis of the collaborative design process. Second, the purpose of a refurbishment project was reviewed again from a different perspective using the Soft System Methodology, which gave rise to the root definition (the core purpose) of the system under consideration. Though the root definition was eventually superceded by another (Section 3.3), these concepts formed the basis for the eventual development of the Preliminary Collaboration Model (Figure 9). Third, the paper stated that the representation of an agreement between project team members could be defined in terms of ownership of an information item, Figure 13.

The AUTCON paper was revised prior to publication as a result of comments received from the reviewers. The concern of the reviewers were twofold. First, a tangible solution was expected in addition to the proposed methodology. Consequently, the 'Preliminary Collaboration Model' was added. Second, the "comparison" of agents and hypermedia was considered to be inappropriate. In this connection, it was further explained that there was never any intention to compare agents and hypermedia directly. The purpose of raising such issues was to argue that different tactics of handling information might be applied to different parts of a collaboration process. In other words, as far as a shopping centre refurbishment project was concerned, the need of a tool for organizing information using hypermedia was thought to be more productive than a very intelligent system typically found in agent-based applications.

INCITE 2000

Finally, the concept that an appropriate architecture of organizing design information might facilitate the collaborative design process was proposed and published in the International Conference on Construction Information Technology 2000 (INCITE 2000). The title of the paper was "Collaborative Design: A Process Model for Refurbishment". According to the Conference Proceedings, submitted papers were grouped under five different themes:

- Theme 1: Organization and Management of IT
- Theme 2: Information Management System
- Theme 3: Virtual Environments
- Theme 4: Methods and Software
- Theme 5: Electronic Commerce

The paper was placed under Theme 3, i.e. Virtual Environments. The collaboration matrix elaborated in the paper was perceived as a dynamic system representing a real world problem. It echoed one of the basic concepts, i.e., a meaningful representation of the real world objects is essential for the development of a collaborative system.

6.2 Conclusions

I. The analysis of the primary information elements in respect of the development of the client's brief in refurbishing a shopping centre is carried out. The results suggest that the design activities of each project team member can be represented by a typical basic information model comprising a fixed data set as well as a variable data set. Fixed data typically include engineering design standards, building regulations, existing conditions of a shopping centre as well as the prevailing social norm and political background. Variable data are the improvement proposals and specific design requirements, and the views and actions of individual PT members.

II. The connection of the basic information models of respective project team members results in the preliminary collaboration model. It gives rise to a complex problem situation that warrants a flexible approach to resolving the problem, i.e. not solutions to predetermined problems. This complex problem is analyzed using the soft system methodology, which defines the root definition or core purpose of refurbishing a shopping centre, i.e. the acquisition of a design information set that can be retrieved more effectively in comparison to the conventional practice undertaken by BSE, HM, MS and SE subject to the three-tier authorization hierarchy of HKHA.

III. Variable data of the preliminary collaboration model constitute the critical information type pertaining to the collaboration of PT members in meeting the requirements of the root definition.

IV. The strength of classification of relations between information objects in enhancing the effectiveness of hypermedia systems, subsides in a collaborative working environment requiring a sequential representation of collaboration events. Such a representation is not readily available in the classification approach.

V. Notwithstanding the limitation of the classification of relations between information objects, the classification approach does provide the framework for defining an agreement in hypermedia terms between PT members with regard to a design information object. As such, an agreement implies that all PT members have the same relation ('propose' or 'own') to the object in question.

VI. A collaboration matrix can represent the variation of a 'propose' relation with regard to its positive sense as well as negative sense against different design options hence providing the required framework to track the sequence of collaboration events.

VII. A 'PT member' cannot be emulated in a single hypermedia node which should represent at least one collaboration matrix, while the collaboration process can be manifested as many connected collaboration matrices:- the Collaborative Design Hypermedia Model (CDHM).

VIII. The conceptual CDHM is prototyped by defining an architecture of the design information in four levels conforming to the common practice of PT members. This can meet the performance requirements in concurrency control as well as resolving 'no agreement' situations under an asynchronous mode of collaboration.

IX. The CDHM provides a direct and effective means for a building services engineer of an in-house design team to capture and retrieve design information in developing a client's brief with regard to the refurbishment of a shopping centre.

X. The CDHM provides a relatively open environment where a client's brief for the refurbishment of shopping centre can evolve in an interactive manner through the collaboration between PT members who are not bound by any pre-conditions.

XI. The collaborative design process can be represented meaningfully in hypermedia provided the representation is implemented under a multi-level configuration in respect of the design information. The multi-level configuration allows a PT member to act as an author as well as a reader for the same document. It enables the tracking of archived information by navigation and allows access to any previous design decision with certainty instead of interpreting a set of searched data which is not fully relevant to a query.

6.3 Recommended future work

The future development of CDHM can be contemplated in at least two directions. First, its scope of application can be extended to the construction stage in such a way that the design activities of the contractor may be integrated with the client's brief. Obviously there are limitations in reconciling the contractor's design with that of the client. As far as building services engineering systems are concerned, a contractor's design will involve the setting out of the routing of various service pipes and ducts through the heavy use of graphics such as shop drawings. CDHM is weak in handling graphics on the one hand and on the other is proficient in the articulation of design intent primarily in a text-based environment. Much work has to be done to investigate the relationship between these two different modes of expressing design intent. Perhaps IFC is one of the alternatives.

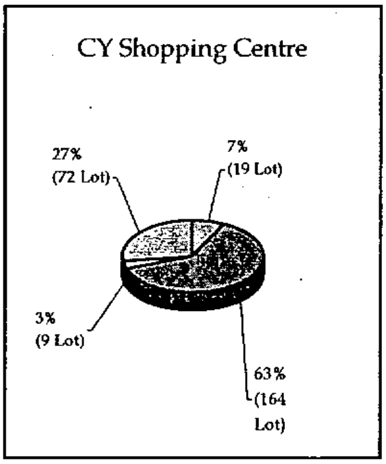
Notwithstanding the debate whether the Internet is a true hypermedia system or not (Section 3.8), the proliferation of e-business will certainly give rise to a client's expectation to have a fully Internet-based CDHM. While the effort for porting CDHM to the World Wide Web environment is not prohibitive, a fundamental question has to be answered before the shift of the operating platform of CDHM, "What is the implication of collaborating in a synchronous mode with regard to the productivity of the design process?" A similar question can be asked regarding the real benefit of having several people at different locations simultaneously working on the same drawing through WWW. CDHM has provided the fundamental concepts and logic in respect of the procedures essential for collaboration to capture and organize design intents. Further application in WWW is deemed as another major area of research.

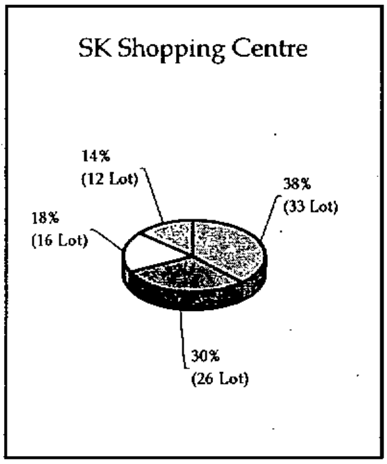
APPENDIX ONE

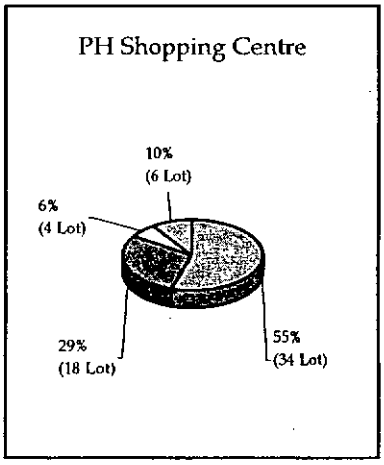
APPENDIX 1

Results of survey to design document records of three shopping centre improvement projects

Project Title	CY Shopping Centre				SK Shopping Centre				PH Shopping Centre			
Building Main Contract Sum	$95,300,000				$26,679,812.69				$13,380,022			
Electrical Sub-contract	$6,650,000 (included in Building Main Contract)				$2,724,885 (included in Building Main Contract)				$1131400 (included in Building Main Contract)			
Fire Services Sub-contract	$1,471,840 (included in Building Main Contract)				$699,340 (included in Building Main Contract)				$379,806 (included in Building Main Contract)			
Air-conditioning Sub-contract	$7,730,000 (included in Building Main Contract)				---				---			
Lift / Escalator seperate contract	$4,905,800				$1,720,000				---			
Total Project Sum	$100,205,800				$28,399,812.69				$13,380,022			
	Preliminary Design (23.6.93 - 23.2.94)		Detail Design (24.2.94 - 20.12.96)		Preliminary Design (16.5.97 - 21.5.99)		Detail Design (22.5.99 - 1.2.00)		Preliminary Design (16.5.96 - 28.11.97)		Detail Design (29.11.97 - 2.11.98)	
Document Type Text vs. Text w/ Drawing	Text	Text w/ Drawing	Text	Text w/ Drawing	Text	Text w/ Drawing	Text	Text w/ Drawing	Text	Text w/ Drawing	Text	Text w/ Drawing
Quantity (Lot)	19	9	164	72	33	16	26	12	34	4	18	6







APPENDIX TWO

Grouping of design activites vs. information type based on archived project records of FSH SC improvement project

Document Type	Date	Background Information	Improvement Objective/ Strategy	Improvement Proposals (Major requirements)	Scope of Work (Location of major facilities) / Materials, Plant Sizing, Construction Details (#)
1st Case Meeting (Notes of Meeting)	26.6.1996	♦ Environmental and Central A/C ♦ Marketing Study ♦ Circulation Study ♦ Condition Appraisal ♦ Structural Appraisal ♦ Previous/ Short-term planned improvement work ♦ SWOT analysis	♦ Central A/C ♦ Cooked Food Stall relocation ♦ Decking Over ♦ Retail increase ♦ Finishes ♦ Performance Venue	♦ Central A/C to market and common area of shopping centre ♦ Retail addition of 600 m^2 ♦ Lighting improvement ♦ Renew false ceiling ♦ Additional escalators ♦ Cover to performance venue ♦ Signage improvement	
Memo from HM to MS and BSE	18.7.1996			♦ Data for A/C charges	♦ Location for transformer house and main switch room ♦ Location for chiller plant house
Memo from BSE to HM	24.7.1996			♦ Data for A/C charges	
2nd Case Meeting (Notes of Meeting)	29.7.1996	♦ Data of existing Mechanical ventilation system of market		♦ Different scenario of central A/C ♦ Performance stage cover ♦ External façade renovation ♦ False ceiling replacement ♦ Lighting improvement ♦ Signage improvement ♦ Exit/ smoke doors replacement ♦ Existing railing touch-up	♦ Location of chiller plant house ♦ Location of transformer house ♦ Retail increase: conversion of store house into shop stalls ♦ Location of new escalator ♦ Replacement of parapets at the voids of 1/F arcade
Memo from HM to MS (cc. SE and BSE)	27.8.1996				♦ Structural feasibility of Chiller plant house ♦ Technical feasibility of transformer house
Memo from MS to HM (cc. SE and BSE)	30.8.1996				♦ Location of transformer house ♦ Location of chiller plant room
Memo from HM to MS (cc. SE and BSE)	30.8.1996				♦ Location of transformer house ♦ Location of chiller plant room
Memo from BSE to HM (cc. MS and SE)	20.9.1996				♦ Location of transformer house ♦ Location of chiller plant room
Project Design Meting	15.11.196		♦ Central A/C option deleted	♦ Proposal to provide performance stage	

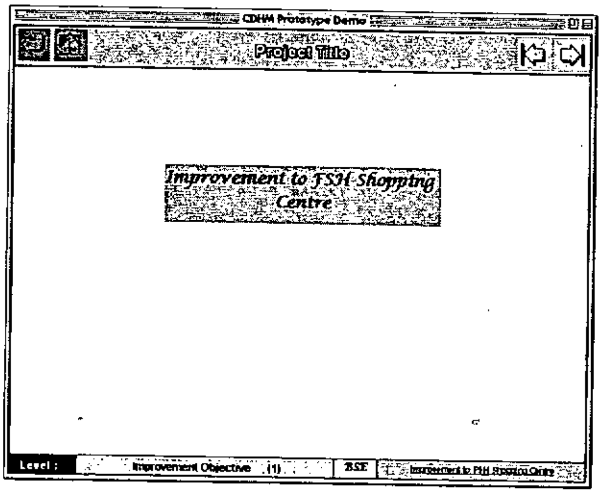
(Notes of Meeting)				cover shelved ♦ Renovation of external façade ♦ Replacement of Exit/Smoke doors ♦ Replacement of false ceiling ♦ Lighting improvement ♦ Signage improvement ♦ Existing railing touch-up ♦ Parapet wall replacement	
Memo from HM to MS, BSE and SE	18.11.1996		♦ Request for general comment	♦ Request for cost estimate	
Memo from BSE to HM	26.11.1996			♦ Reply for cost estimate	
Memo from MS to HM	18.12.1996			♦ Reply for cost estimate	
Draft Design Brief (from HM to MS, BSE and SE)	18.12.1996	♦ Shopping centre history and general layout	♦ Improvement objectives	♦ Addition of retail space ♦ Vertical accessibility ♦ Transformer room, switch room and meter room ♦ Fire service facilities ♦ Finishes ♦ Lighting ♦ Signage system	
Memo from BSE to HM	30.12.1996		♦ Agreement to draft design brief	♦ Agreement to draft design brief	
Memo from MS to HM	7.1.1997		♦ Agreement to draft design brief	♦ Agreement to draft design brief except the IFA of new shop changed from 600 m^2 to 440 m^2	
Memo from SE to HM	8.1.1997		♦ No comment to draft design brief	♦ No comment to design brief except additional requirement to foundation	
Case Conference (Notes of Meeting)	29.1.1997		♦ Draft design brief endorsed in principle	♦ Draft design brief endorsed in principle	♦ Exact location of new shops to be further explored ♦ Location of transformer house to be further explored ♦ External façade renovation should be cost-effective: consider tile filler in lieu of total re-tiling (#)

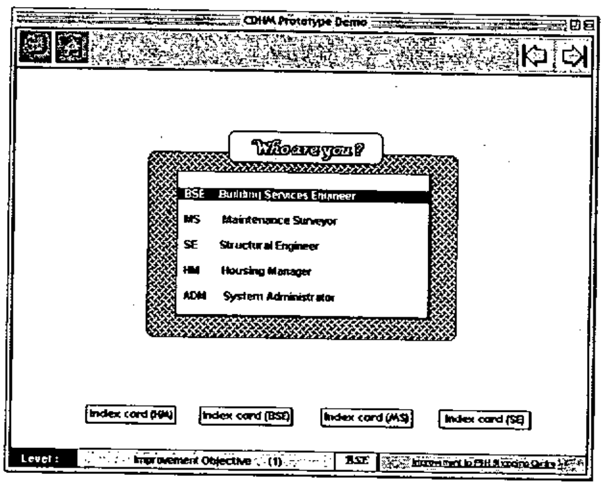
APPENDIX THREE

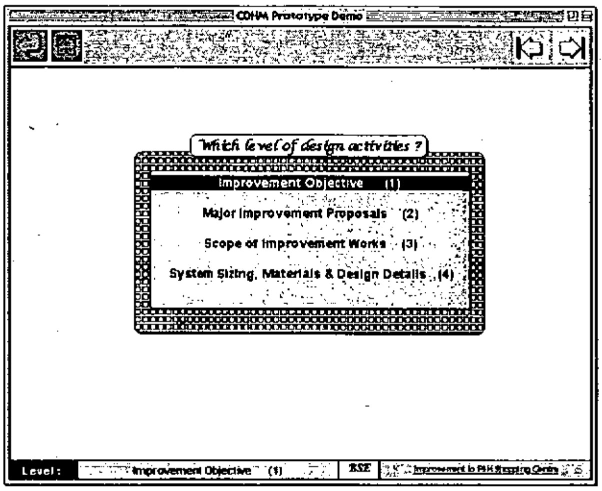
APPENDIX 3

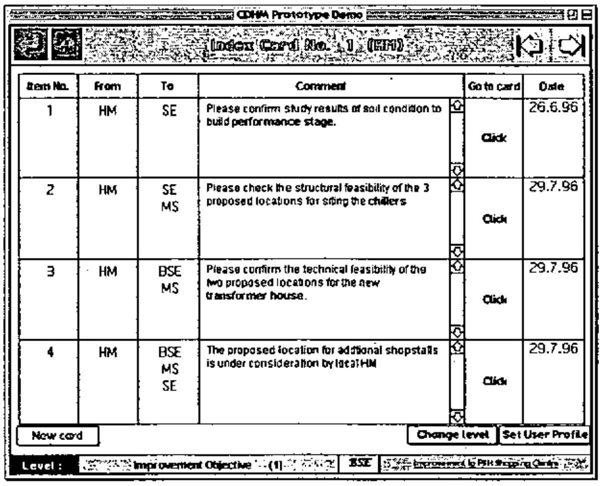
Printout of CDHM cards (full set)

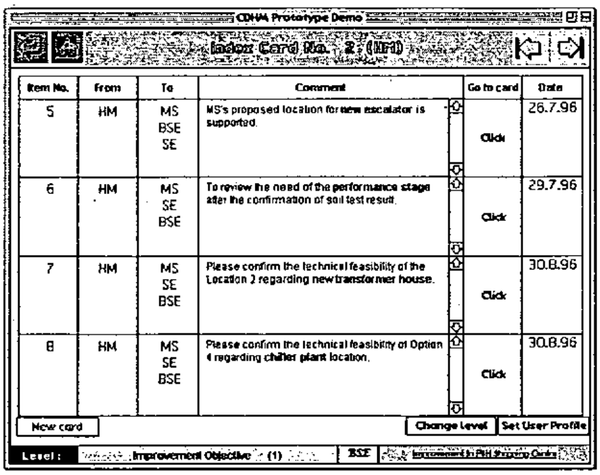
Remarks: The cards of CDHM are shown according to the order that a card was added into the HyperCard stack in a sequential manner and these are for reference purpose only. It should not be seen as the actual sequence in the development of a client's brief.

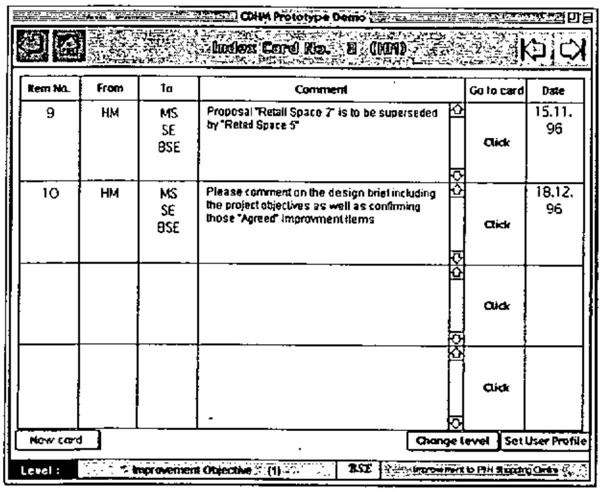


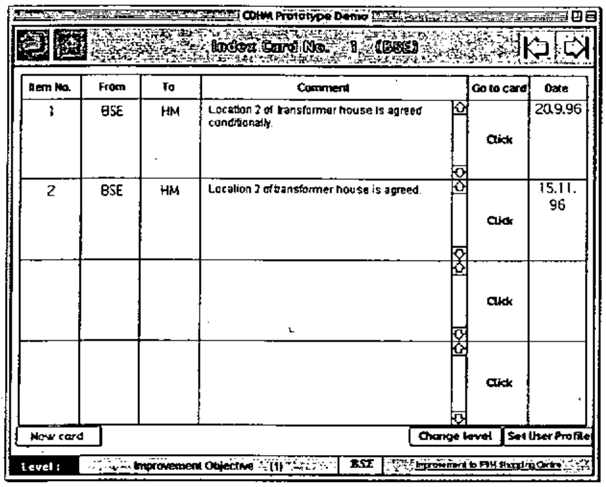


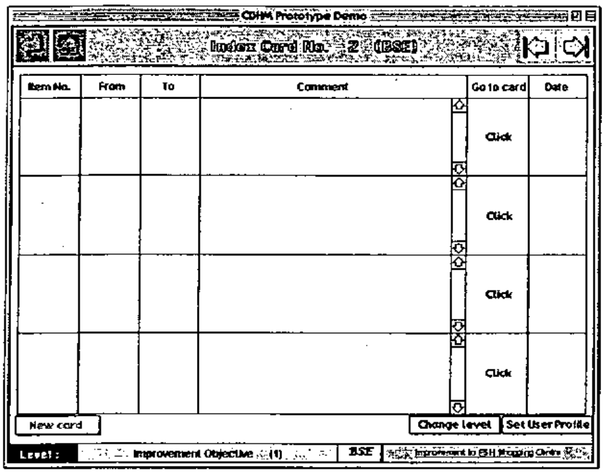

CDHM Prototype Demo
Which level of design activities ?
Improvement Objective (1)
Major Improvement Proposals (2)
Scope of Improvement Works (3)
System Sizing, Materials & Design Details (4)
Level :
Improvement Objective (1)
BSE


CDHM Prototype Demo
Index Card No. 1 (HM)
Item No.
From
To
Comment
Go to card
Date
1
HM
SE
Please confirm study results of soil condition to build performance stage.
Click
26.6.96
2
HM
SE
MS
Please check the structural feasibility of the 3 proposed locations for siting the chillers
Click
29.7.96
3
HM
BSE
MS
Please confirm the technical feasibility of the two proposed locations for the new transformer house.
Click
29.7.96
4
HM
BSE
MS
SE
The proposed location for additional shopstalls is under consideration by local HM
Click
29.7.96
New card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE


CDHM Prototype Demo
Index Card No. 2 (HM)
Item No.
From
To
Comment
Go to card
Date
5
HM
MS
BSE
SE
MS's proposed location for new escalator is supported.
Click
26.7.96
6
HM
MS
SE
BSE
To review the need of the performance stage after the confirmation of soil test result.
Click
29.7.96
7
HM
MS
SE
BSE
Please confirm the technical feasibility of the Location 2 regarding new transformer house.
Click
30.8.96
8
HM
MS
SE
BSE
Please confirm the technical feasibility of Option 4 regarding chiller plant location.
Click
30.8.96
New card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE


CDHM Prototype Demo
Item No.
From
To
Comment
Go to card
Date
9
HM
MS SE BSE
Proposal "Retail Space 2" is to be superseded by "Retail Space 5"
Click
15.11.96
10
HM
MS SE BSE
Please comment on the design brief including the project objectives as well as confirming those "Agreed" improvment items
Click
18.12.96
Click
Click
New card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE


CDHM Prototype Demo
Index Card No. 1 (BSE)
Item No.
From
To
Comment
Go to card
Date
1
BSE
HM
Location 2 of transformer house is agreed conditionally.
Click
20.9.96
2
BSE
HM
Location 2 of transformer house is agreed.
Click
15.11.96
Click
Click
New card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE


CDHM Prototype Demo
Index Card No. 2 (BSE)
Item No.
From
To
Comment
Go to card
Date
Click
Click
Click
Click
New card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

CDHM Prototype Demo

Index Card No. 1 (MS)

Item No.	From	To	Comment	Go to card	Date
1	MS	HM	For location 2 of chiller plants, there are A/C equipments which are installed by shop tenants. Please confirm if they can be reloacated in order to allow adequate space for the 4 new chillers.	Click	29.7.96
2	MS	HM BSE SE	Please consider another proposal for additional retail space.	Click	29.7.96
3	MS	HM	Please check estate vesting order to confirm estate boundary near bus terminus regarding the extension of shop fronts into pavement area.	Click	15.11.96
				Click	

New card | Change level | Set User Profile

Level: Improvement Objective (1) | BSE

CDHM Prototype Demo

Index Card No. 2 (MS)

Item No.	From	To	Comment	Go to card	Date
				Click	
				Click	
				Click	
				Click	

New card | Change level | Set User Profile

Level: Improvement Objective (1) | BSE

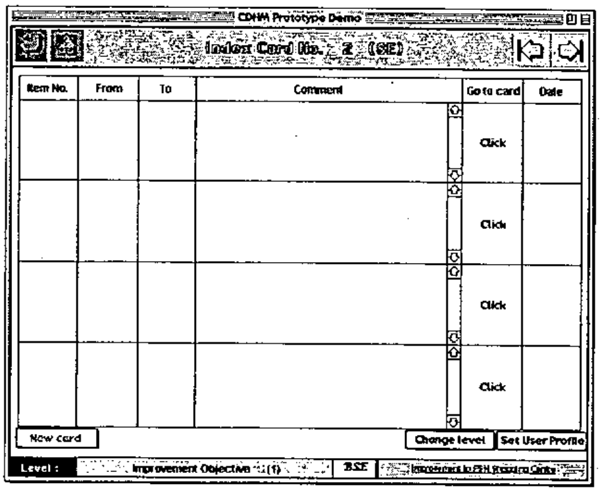
CDHM Prototype Demo

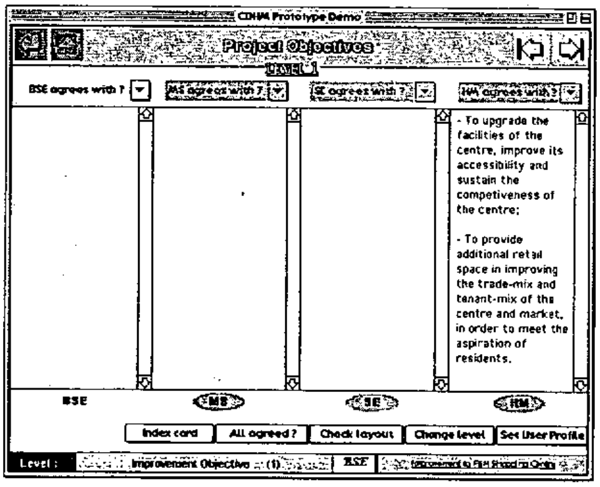
Index Card No. 1 (SE)

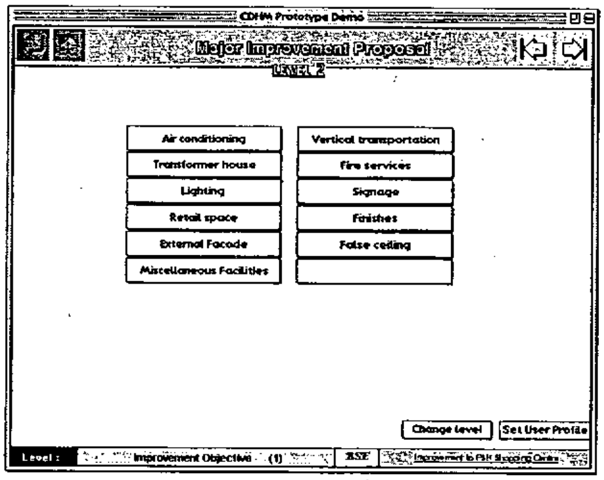
Item No.	From	To	Comment	Go to card	Date
1	SE	HM	A/C to whole shopping centre is necessary if decking over the void area on 1/F.	Click	26.6.96
2	SE	HM	Soil condition unsuitable for raft foundation and mini-pile might be required w.r.t. performance stage.	Click	26.6.96
3	SE	HM MS BSE	The proposed location of new escalators near Shop G11 woulod create nuisance to tenants as columns are found inside the shops.	Click	29.7.96
4	SE	HM MS BSE	The construction cost of performance stage may exceed $5M because piling would be required due to poor soilo condition.	Click	29.7.96

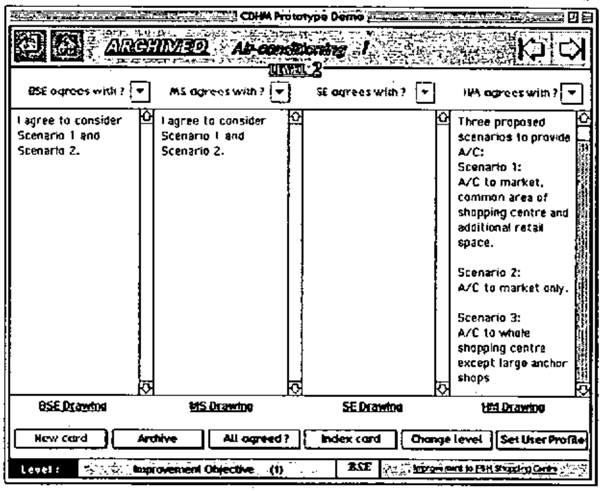
New card | Change level | Set User Profile

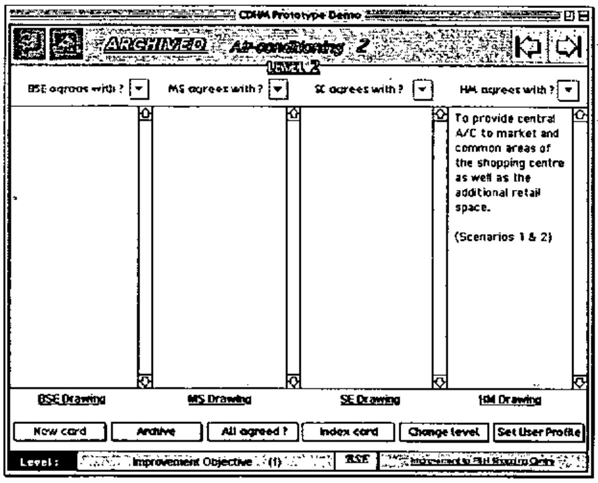
Level: Improvement Objective (1) | BSE

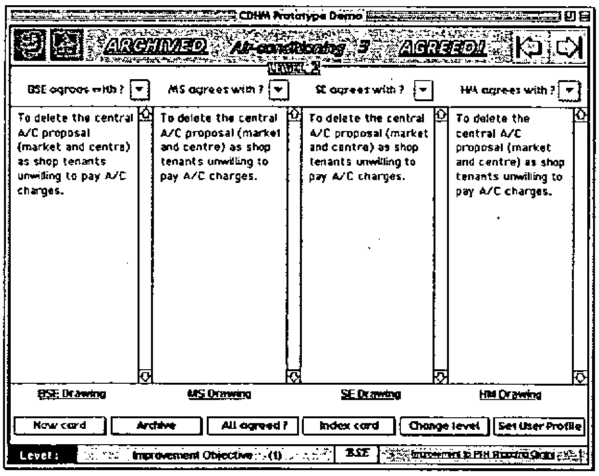

CDHM Prototype Demo
Index Card No. 2 (SE)
Item No.
From
To
Comment
Go to card
Date
Click
Click
Click
Click
New card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

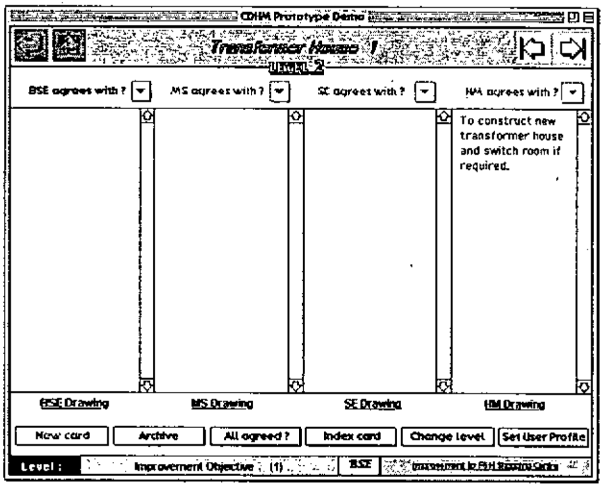

CDHM Prototype Demo
Project Objectives
LEVEL 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
- To upgrade the facilities of the centre, improve its accessibility and sustain the competiveness of the centre;
- To provide additional retail space in improving the trade-mix and tenant-mix of the centre and market, in order to meet the aspiration of residents.
BSE
MS
SE
HM
Index card
All agreed ?
Check layout
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

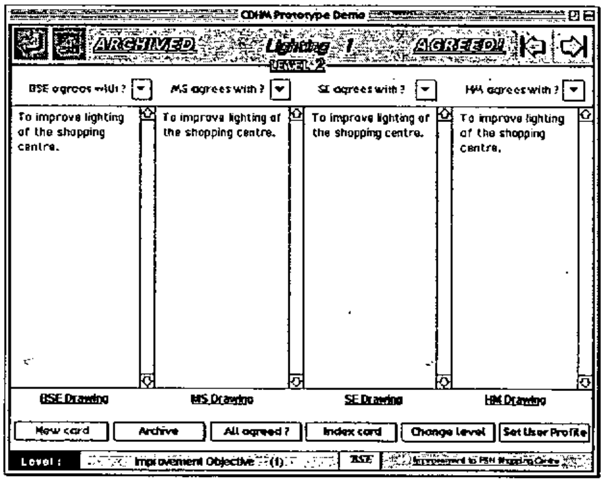

CDHM Prototype Demo
Major Improvement Proposal
LEVEL 2
Air conditioning
Vertical transportation
Transformer house
Fire services
Lighting
Signage
Retail space
Finishes
External Facade
False ceiling
Miscellaneous Facilities
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

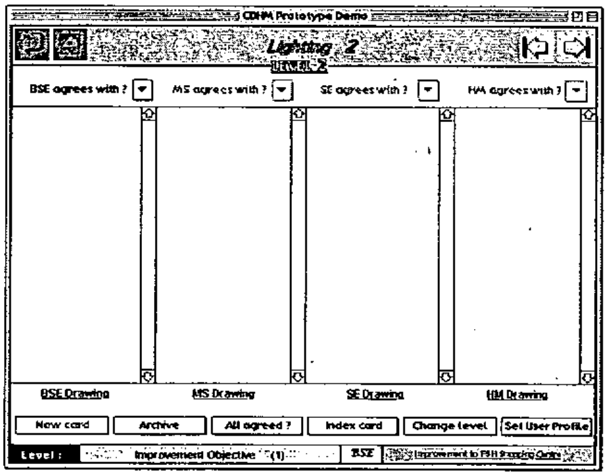

CDHM Prototype Demo
ARCHIVED
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
I agree to consider Scenario 1 and Scenario 2.
I agree to consider Scenario 1 and Scenario 2.
Three proposed scenarios to provide A/C:
Scenario 1:
A/C to market, common area of shopping centre and additional retail space.
Scenario 2:
A/C to market only.
Scenario 3:
A/C to whole shopping centre except large anchor shops
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

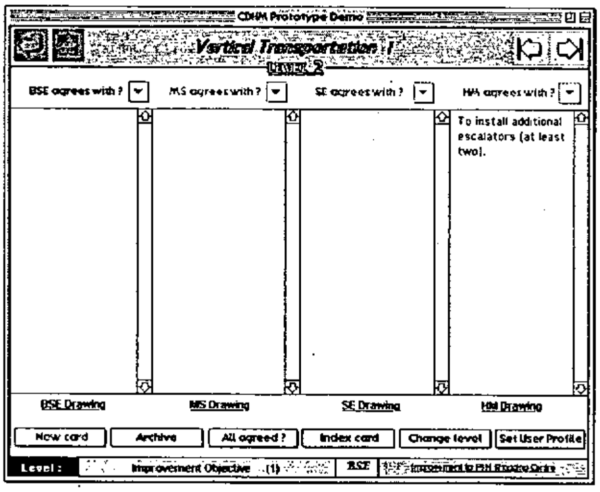

CDHM Prototype Demo
ARCHIVED
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To provide central A/C to market and common areas of the shopping centre as well as the additional retail space.
(Scenarios 1 & 2)
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

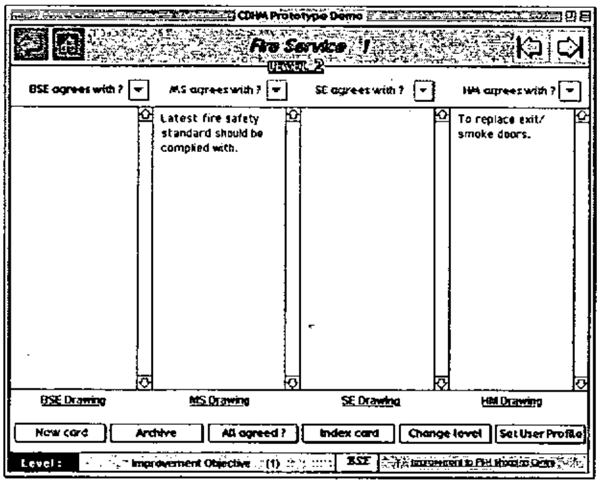

CDHM Prototype Demo
ARCHIVED
AGREED!
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To delete the central A/C proposal (market and centre) as shop tenants unwilling to pay A/C charges.
To delete the central A/C proposal (market and centre) as shop tenants unwilling to pay A/C charges.
To delete the central A/C proposal (market and centre) as shop tenants unwilling to pay A/C charges.
To delete the central A/C proposal (market and centre) as shop tenants unwilling to pay A/C charges.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

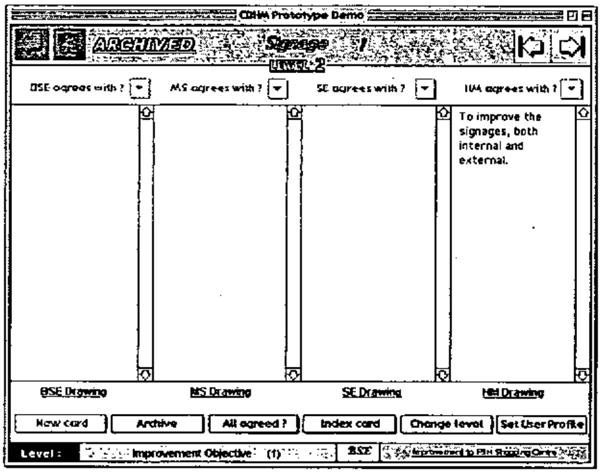

CDHM Prototype Demo
Transformer House 1
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To construct new transformer house and switch room if required.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

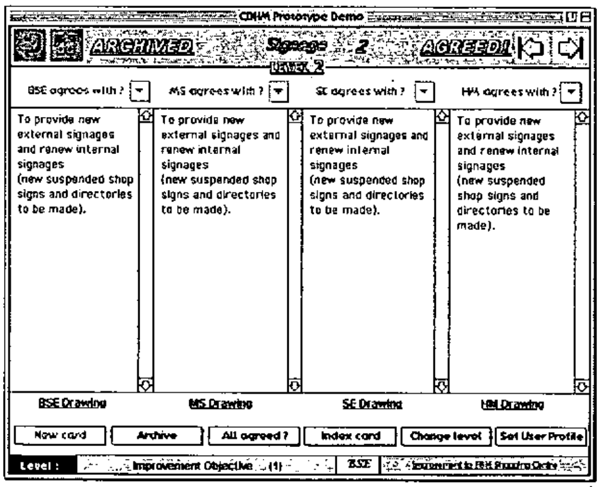

CDHM Prototype Demo
ARCHIVED
Lighting 1
AGREED!
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To improve lighting of the shopping centre.
To improve lighting of the shopping centre.
To improve lighting of the shopping centre.
To improve lighting of the shopping centre.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

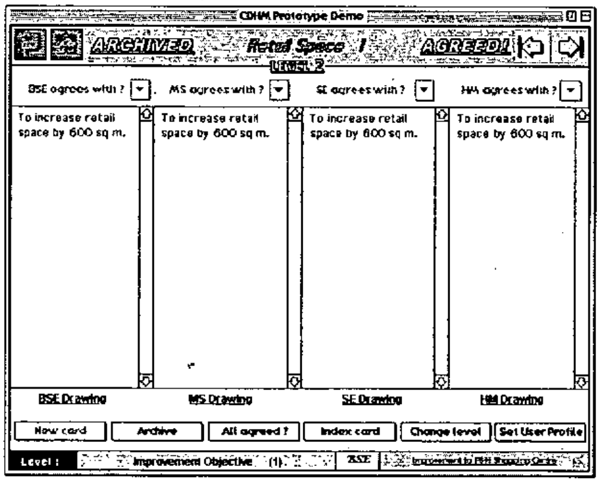

CDHM Prototype Demo
Lighting 2
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

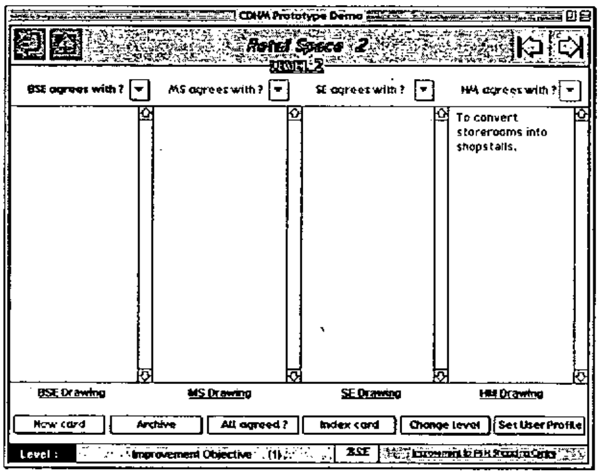

CDHM Prototype Demo
Vertical Transportation
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To install additional escalators (at least two).
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

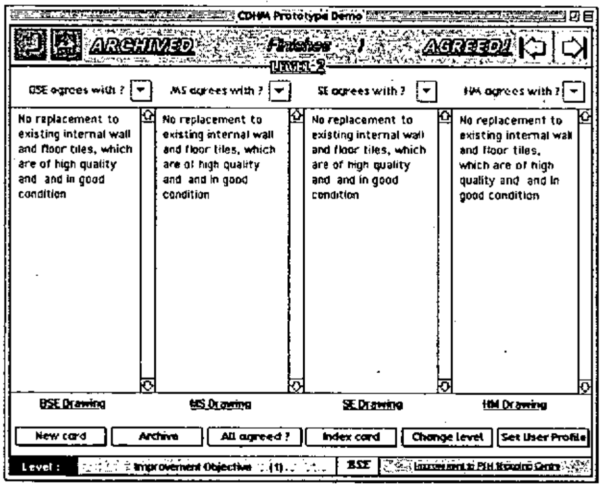

CDHM Prototype Demo
Fire Service
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Latest fire safety standard should be complied with.
To replace exit/ smoke doors.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

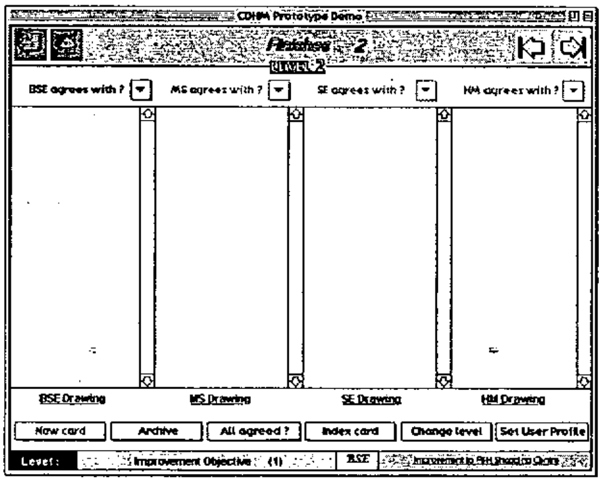

CDHM Prototype Demo
ARCHIVED
Signage
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To improve the signages, both internal and external.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

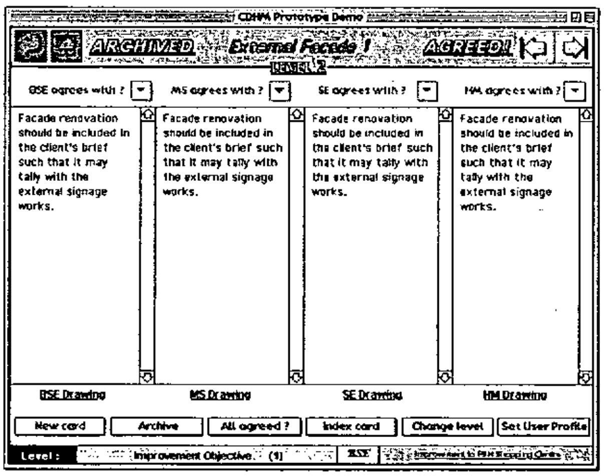

CDHM Prototype Demo
ARCHIVED
Signage 2
AGREED!
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To provide new external signages and renew internal signages (new suspended shop signs and directories to be made).
To provide new external signages and renew internal signages (new suspended shop signs and directories to be made).
To provide new external signages and renew internal signages (new suspended shop signs and directories to be made).
To provide new external signages and renew internal signages (new suspended shop signs and directories to be made).
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

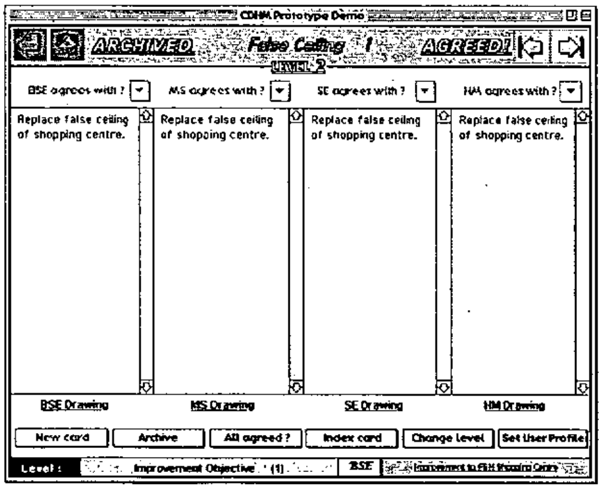

CDHM Prototype Demo
ARCHIVED
Retail Space 1
AGREED!
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To increase retail space by 600 sq m.
To increase retail space by 600 sq m.
To increase retail space by 600 sq m.
To increase retail space by 600 sq m.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

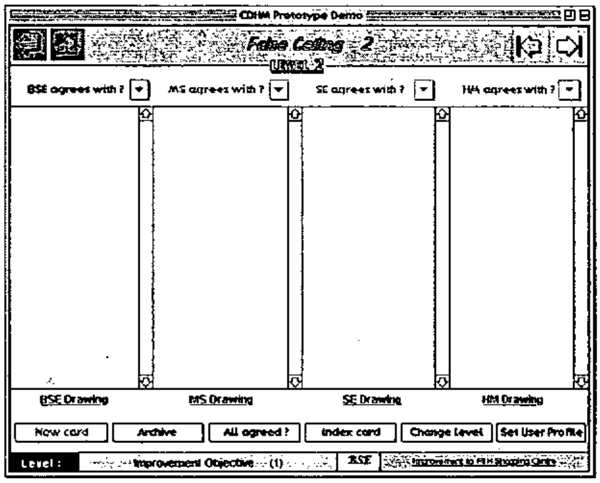

CDHM Prototype Demo
Retail Space 2
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To convert storerooms into shopstalls.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

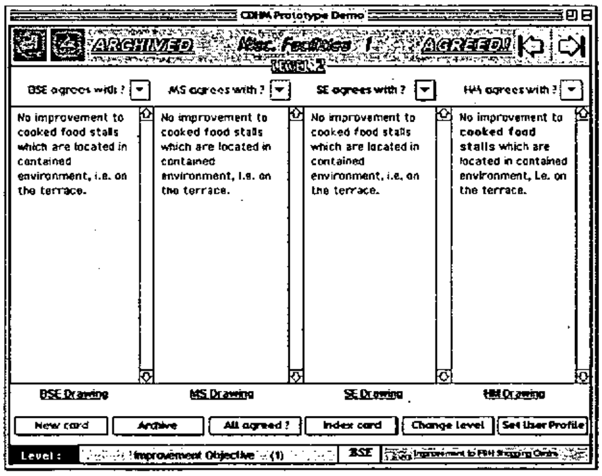

CDHM Prototype Demo
ARCHIVED
Finishes 1
AGREED!
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
No replacement to existing internal wall and floor tiles, which are of high quality and and in good condition
No replacement to existing internal wall and floor tiles, which are of high quality and and in good condition
No replacement to existing internal wall and floor tiles, which are of high quality and and in good condition
No replacement to existing internal wall and floor tiles, which are of high quality and and in good condition
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

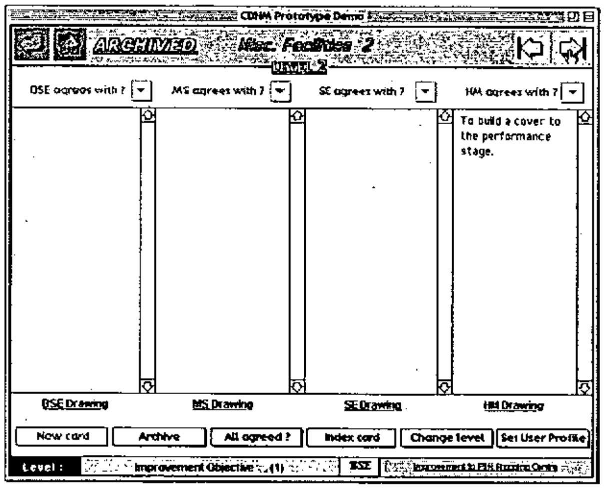

CDHM Prototype Demo
Finishes 2
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

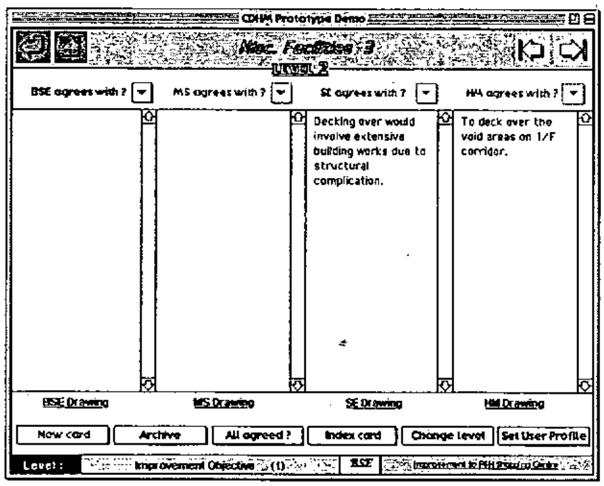

CDHM Prototype Demo
ARCHIVED
External Facade 1
AGREED!
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Facade renovation should be included in the client's brief such that it may tally with the external signage works.
Facade renovation should be included in the client's brief such that it may tally with the external signage works.
Facade renovation should be included in the client's brief such that it may tally with the external signage works.
Facade renovation should be included in the client's brief such that it may tally with the external signage works.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

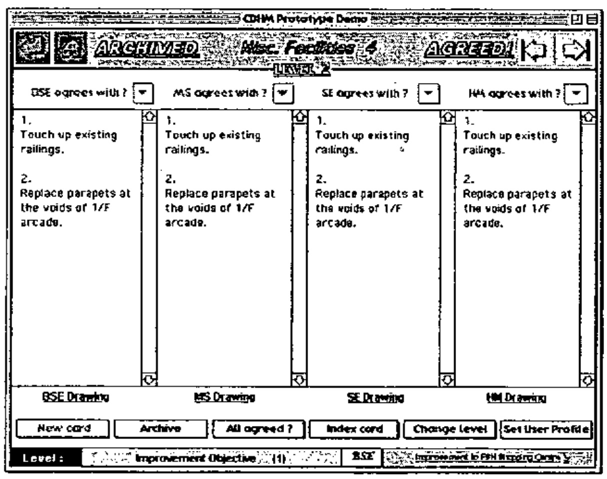

CDHM Prototype Demo
ARCHIVED
False Ceiling 1
AGREED!
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Replace false ceiling of shopping centre.
Replace false ceiling of shopping centre.
Replace false ceiling of shopping centre.
Replace false ceiling of shopping centre.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change Level
Set User Profile
Level :
Improvement Objective (1)
BSE

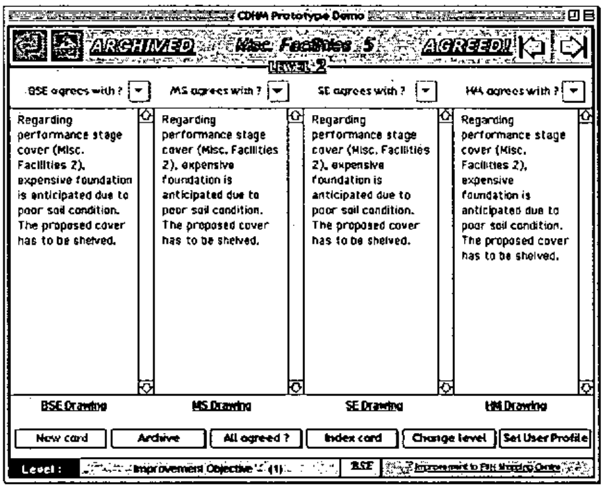

CDHM Prototype Demo
False Ceiling 2
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change Level
Set User Profile
Level :
Improvement Objective (1)
BSE

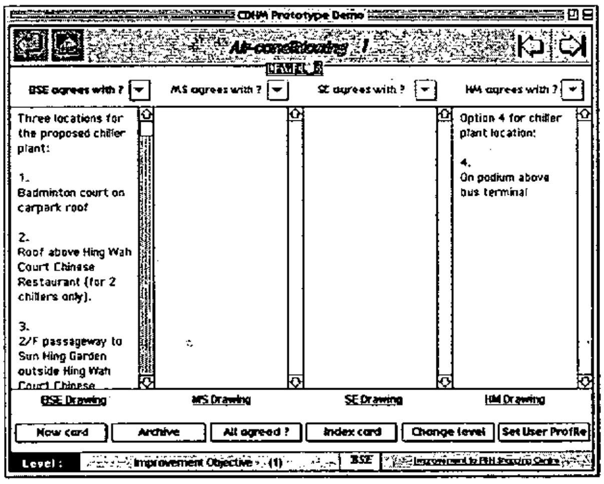

CDHM Prototype Demo
ARCHIVED
Misc. Facilities 1
AGREED!
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
No improvement to cooked food stalls which are located in contained environment, i.e. on the terrace.
No improvement to cooked food stalls which are located in contained environment, i.e. on the terrace.
No improvement to cooked food stalls which are located in contained environment, i.e. on the terrace.
No improvement to cooked food stalls which are located in contained environment, i.e. on the terrace.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change Level
Set User Profile
Level :
Improvement Objective (1)
BSE

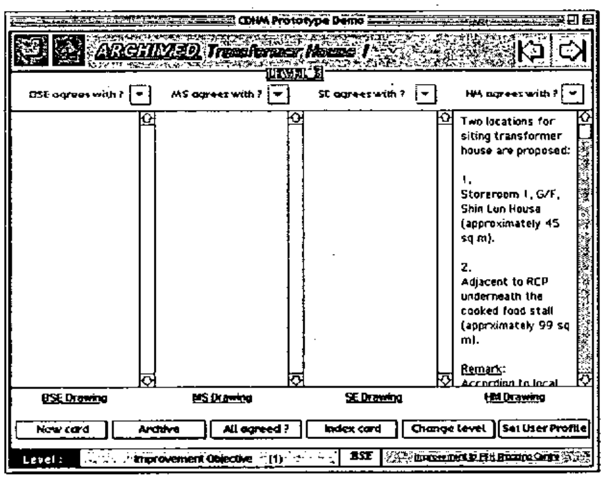

CDHM Prototype Demo
ARCHIVED
Misc. Facilities 2
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To build a cover to the performance stage.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

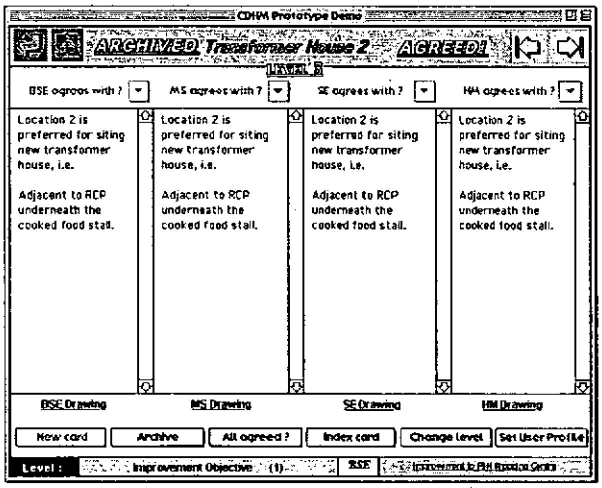

CDHM Prototype Demo
Misc. Facilities 3
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Decking over would involve extensive building works due to structural complication.
To deck over the void areas on 1/F corridor.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

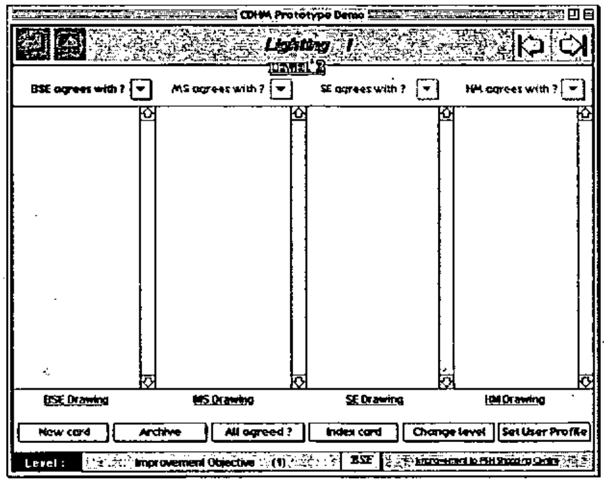

CDHM Prototype Demo
ARCHIVED
Misc. Facilities 4
AGREED!
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
1. Touch up existing railings.
2. Replace parapets at the voids of 1/F arcade.
1. Touch up existing railings.
2. Replace parapets at the voids of 1/F arcade.
1. Touch up existing railings.
2. Replace parapets at the voids of 1/F arcade.
1. Touch up existing railings.
2. Replace parapets at the voids of 1/F arcade.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

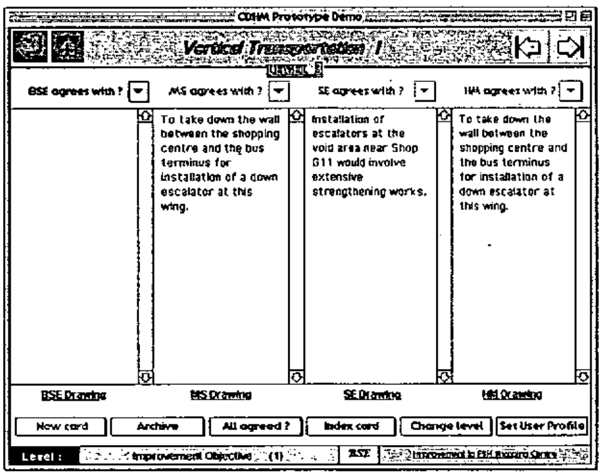

CDHM Prototype Demo
ARCHIVED
AGREED!
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Regarding performance stage cover (Misc. Facilities 2), expensive foundation is anticipated due to poor soil condition. The proposed cover has to be shelved.
Regarding performance stage cover (Misc. Facilities 2), expensive foundation is anticipated due to poor soil condition. The proposed cover has to be shelved.
Regarding performance stage cover (Misc. Facilities 2), expensive foundation is anticipated due to poor soil condition. The proposed cover has to be shelved.
Regarding performance stage cover (Misc. Facilities 2), expensive foundation is anticipated due to poor soil condition. The proposed cover has to be shelved.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

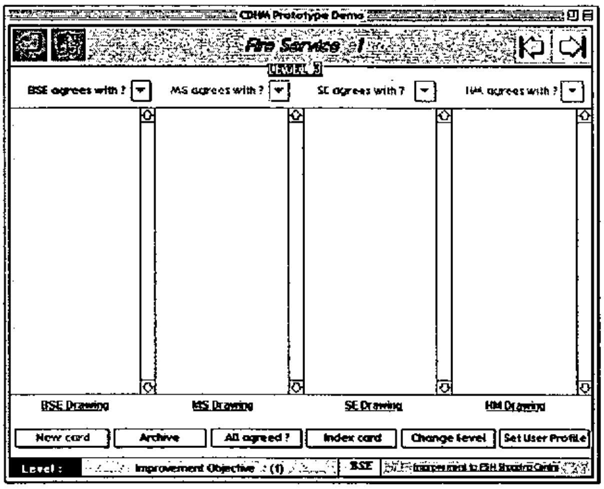

CDHM Prototype Demo
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Three locations for the proposed chiller plant:
1.
Badminton court on carpark roof
2.
Roof above Hing Wah Court Chinese Restaurant (for 2 chillers only).
3.
2/F passageway to Sun Hing Garden outside Hing Wah
Option 4 for chiller plant location:
4.
On podium above bus terminal
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

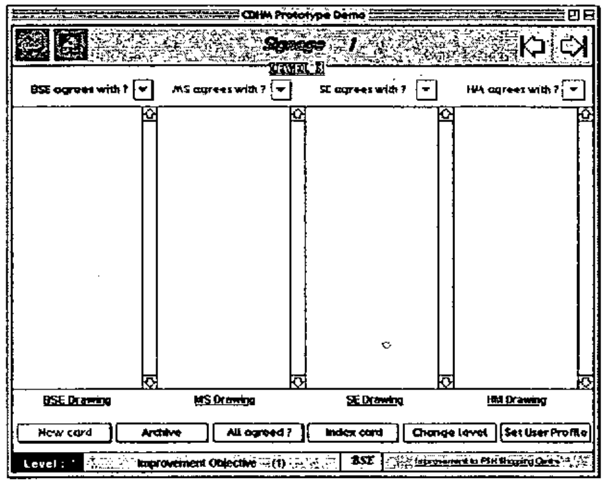

CDHM Prototype Demo
ARCHIVED
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Two locations for siting transformer house are proposed:
1.
Storeroom 1, G/F, Shin Lun House (approximately 45 sq m).
2.
Adjacent to RCP underneath the cooked food stall (approximately 99 sq m).
Remark:
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

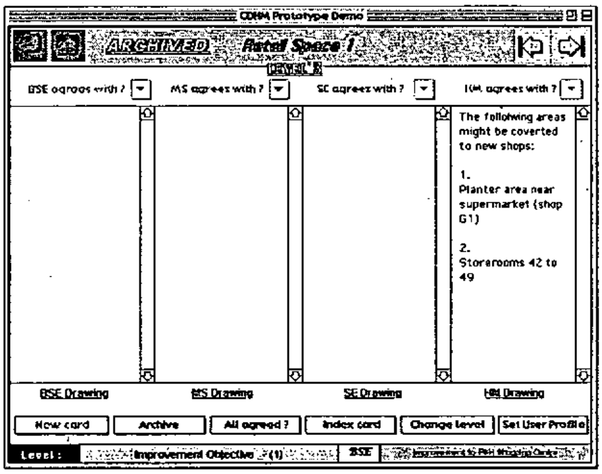

CDHM Prototype Demo
ARCHIVED Transformer House 2 AGREED!
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
Location 2 is preferred for siting new transformer house, i.e.
Adjacent to RCP underneath the cooked food stall.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

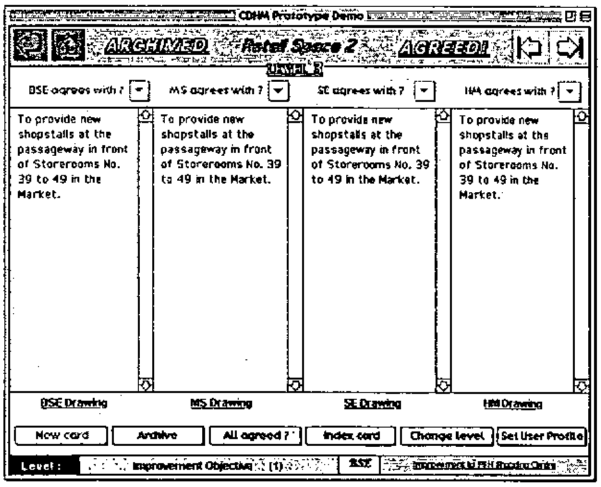

CDHM Prototype Demo
Lighting 1
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

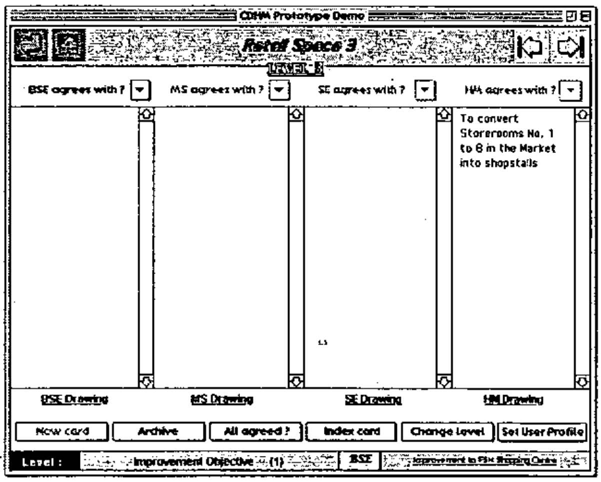

CDHM Prototype Demo
Vertical Transportation 1
LEVEL 2
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To take down the wall between the shopping centre and the bus terminus for installation of a down escalator at this wing.
Installation of escalators at the void area near Shop G11 would involve extensive strengthening works.
To take down the wall between the shopping centre and the bus terminus for installation of a down escalator at this wing.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

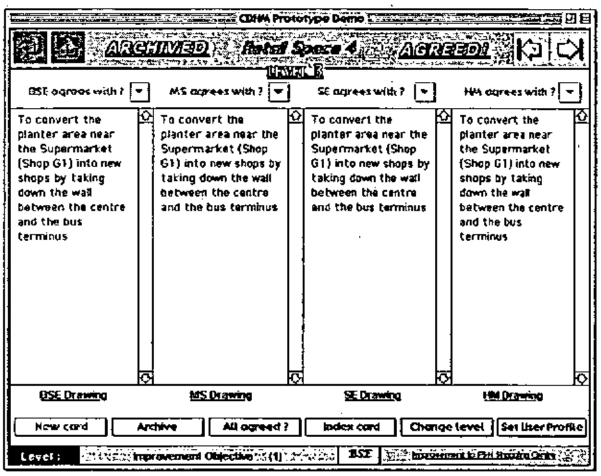

CDHM Prototype Demo
Fire Service 1
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

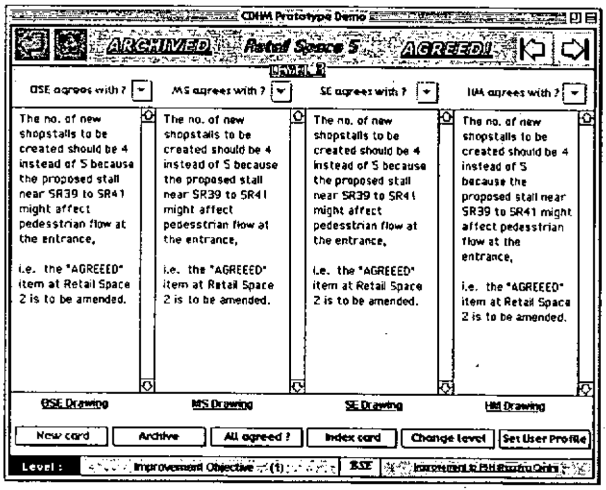

CDHM Prototype Demo
Signage 1
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

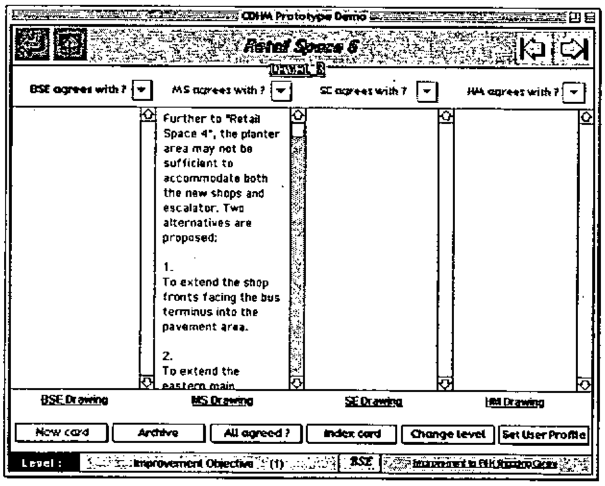

CDHM Prototype Demo
ARCHIVED
Retail Space 1
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
The following areas might be coverted to new shops:
1.
Planter area near supermarket (shop G1)
2.
Storerooms 42 to 49
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

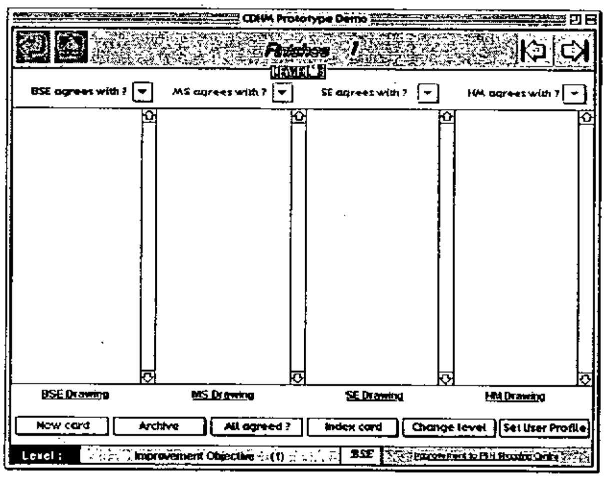

CDHM Prototype Demo
ARCHIVED
Retail Space 2
AGREED!
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To provide new shopstalls at the passageway in front of Storerooms No. 39 to 49 in the Market.
To provide new shopstalls at the passageway in front of Storerooms No. 39 to 49 in the Market.
To provide new shopstalls at the passageway in front of Storerooms No. 39 to 49 in the Market.
To provide new shopstalls at the passageway in front of Storerooms No. 39 to 49 in the Market.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

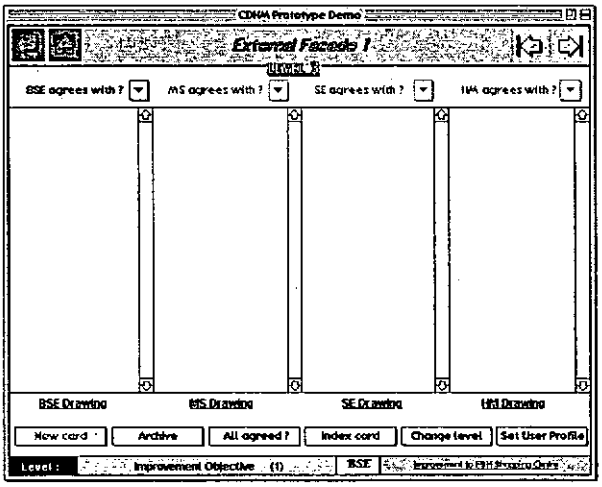

CDHM Prototype Demo
Retail Space 3
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To convert Storerooms No. 1 to 8 in the Market into shopstalls
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

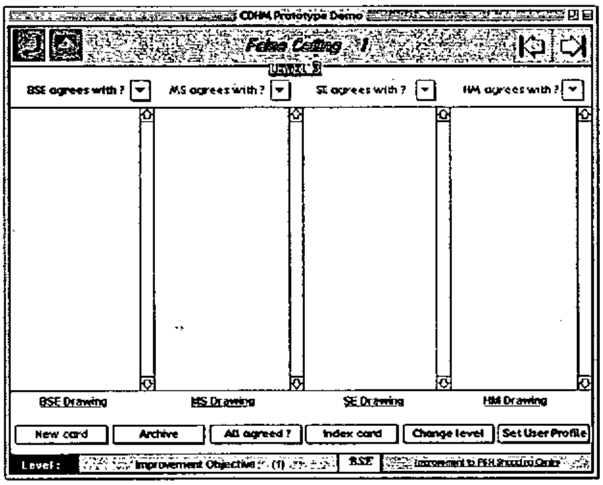

CDHM Prototype Demo
ARCHIVED
Retail Space 4
AGREED!
LEVEL 3
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
To convert the planter area near the Supermarket (Shop G1) into new shops by taking down the wall between the centre and the bus terminus
To convert the planter area near the Supermarket (Shop G1) into new shops by taking down the wall between the centre and the bus terminus
To convert the planter area near the Supermarket (Shop G1) into new shops by taking down the wall between the centre and the bus terminus
To convert the planter area near the Supermarket (Shop G1) into new shops by taking down the wall between the centre and the bus terminus
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

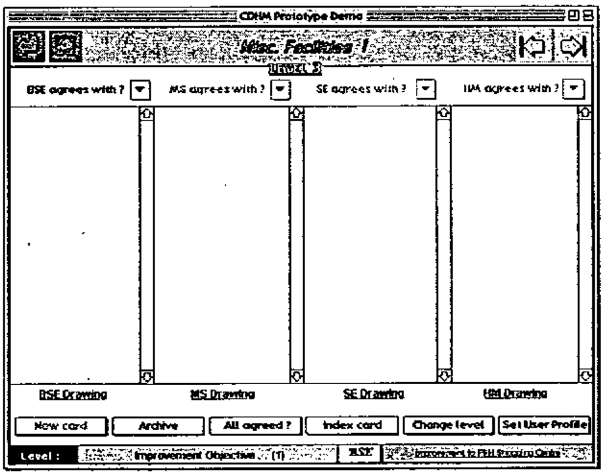

CDHM Prototype Demo
ARCHIVED
Retail Space 5
AGREED!
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
The no. of new shopstalls to be created should be 4 instead of 5 because the proposed stall near SR39 to SR41 might affect pedestrian flow at the entrance,
i.e. the "AGREEED" item at Retail Space 2 is to be amended.
The no. of new shopstalls to be created should be 4 instead of 5 because the proposed stall near SR39 to SR41 might affect pedestrian flow at the entrance,
i.e. the "AGREEED" item at Retail Space 2 is to be amended.
The no. of new shopstalls to be created should be 4 instead of 5 because the proposed stall near SR39 to SR41 might affect pedestrian flow at the entrance,
i.e. the "AGREEED" item at Retail Space 2 is to be amended.
The no. of new shopstalls to be created should be 4 instead of 5 because the proposed stall near SR39 to SR41 might affect pedestrian flow at the entrance,
i.e. the "AGREEED" item at Retail Space 2 is to be amended.
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective
BSE

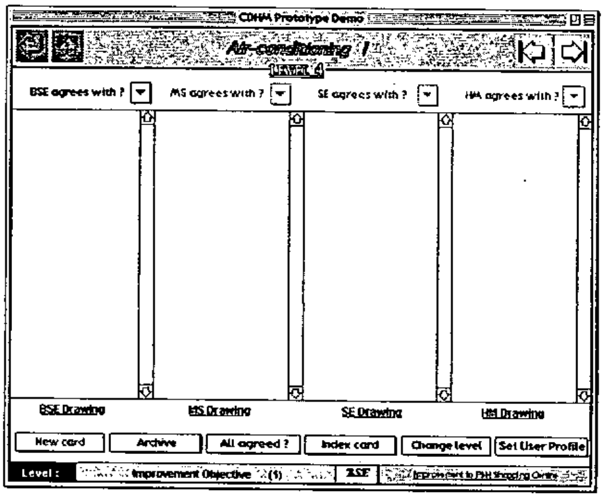

CDHM Prototype Demo
Retail Space 6
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Further to "Retail Space 4", the planter area may not be sufficient to accommodate both the new shops and escalator. Two alternatives are proposed:
1.
To extend the shop fronts facing the bus terminus into the pavement area.
2.
To extend the
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective
BSE

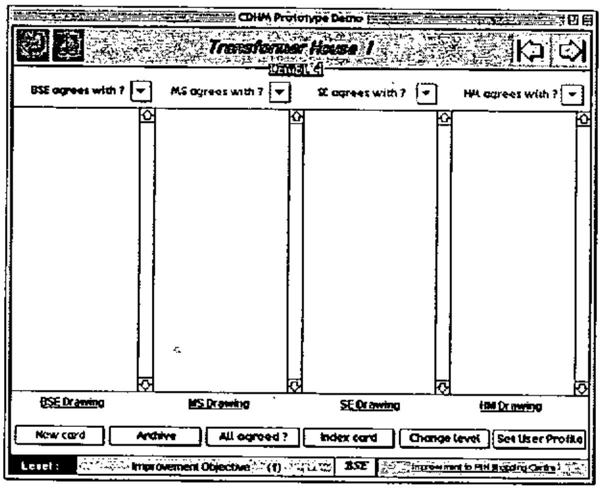

CDHM Prototype Demo
Finishes 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective
BSE

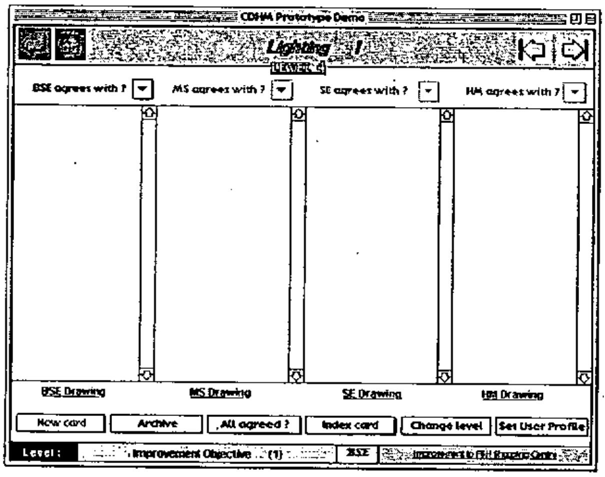

CDHM Prototype Demo
External Facade 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

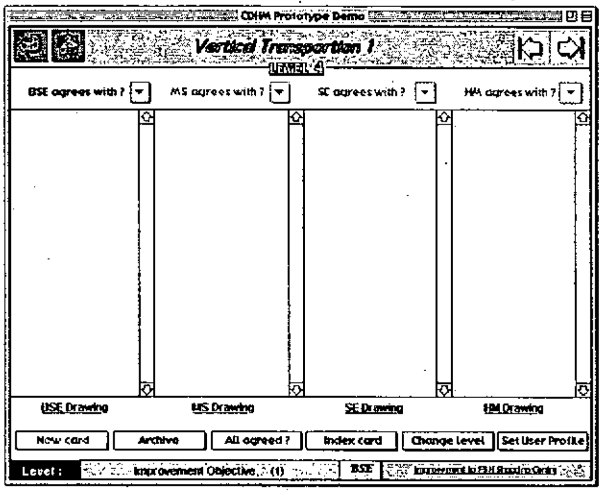

CDHM Prototype Demo
False Ceiling 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

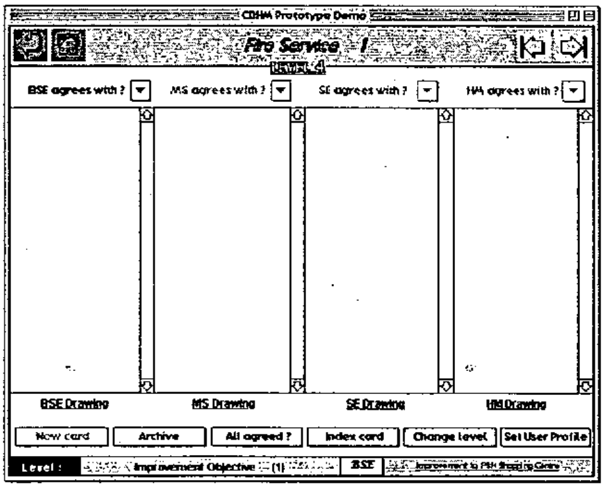

CDHM Prototype Demo
Misc. Facilities 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

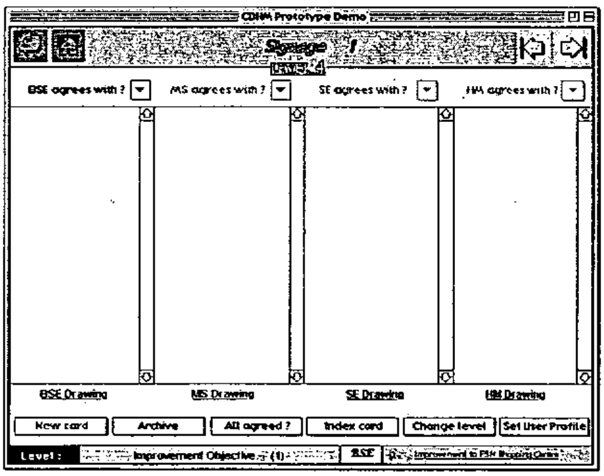

CDHM Prototype Demo
Air-conditioning !
LEVEL 4
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

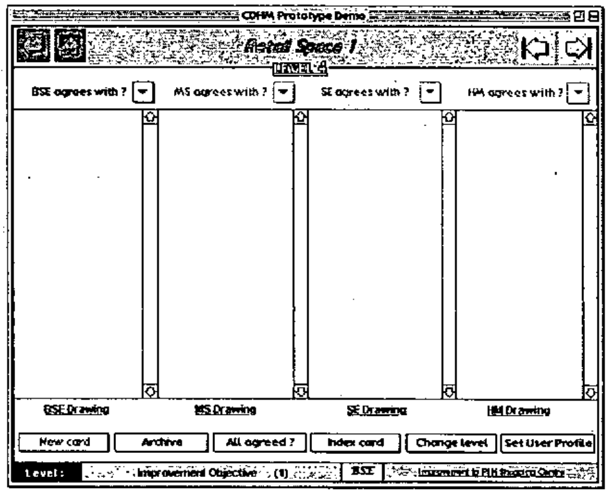

CDHM Prototype Demo
Transformer House !
LEVEL 4
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

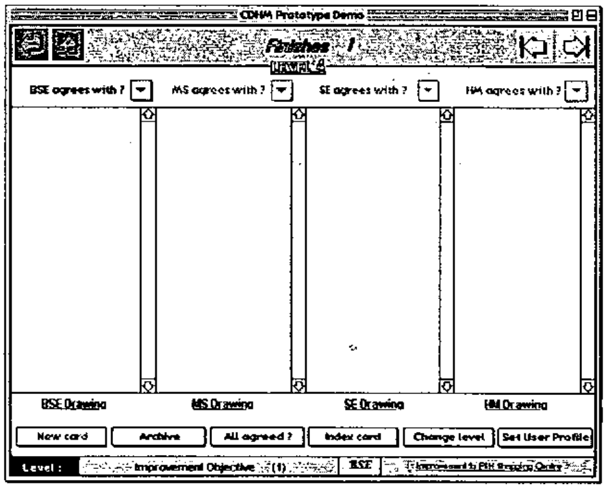

CDHM Prototype Demo
Lighting !
LEVEL 4
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

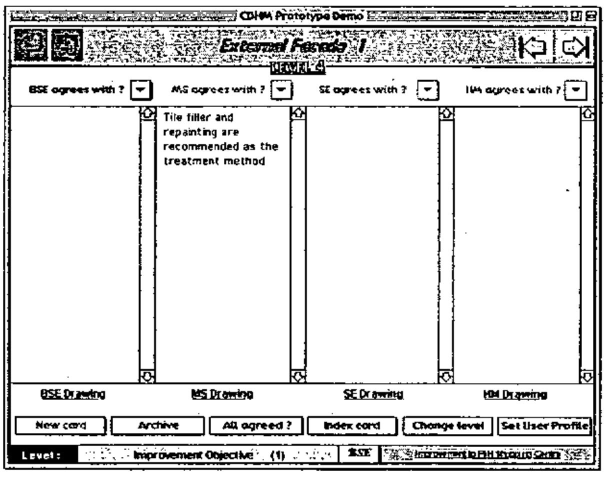

CDHM Prototype Demo
Vertical Transportation 1
LEVEL 4
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

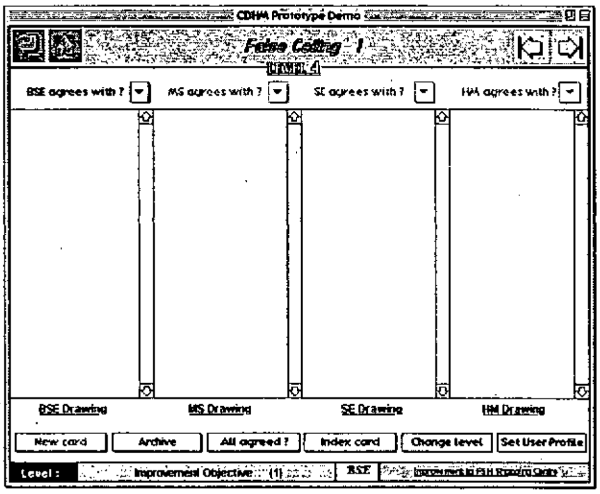

CDHM Prototype Demo
Fire Service 1
LEVEL 4
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

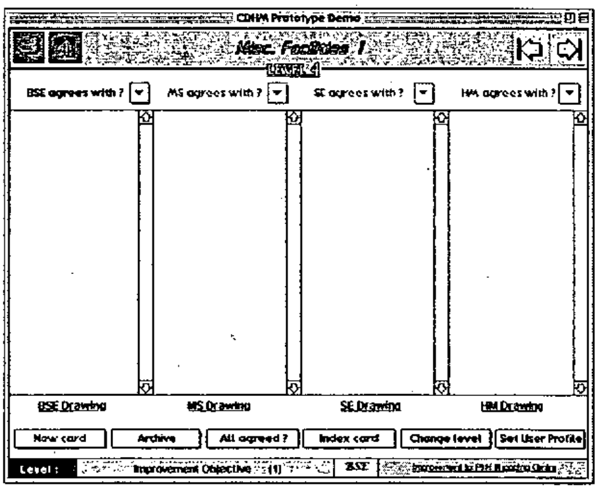

CDHM Prototype Demo
Signage 1
LEVEL 4
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

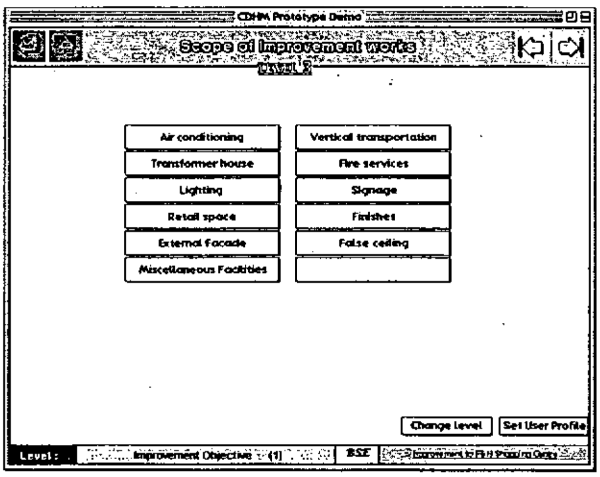

CDHM Prototype Demo
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

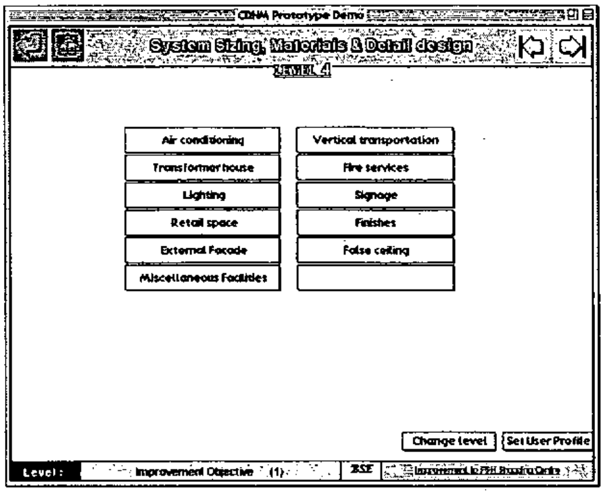

CDHM Prototype Demo
Finishes 1
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE

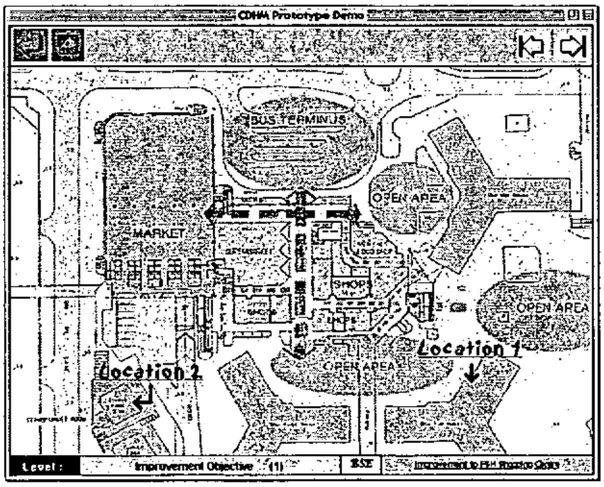

CDHM Prototype Demo
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
Tile filler and repainting are recommended as the treatment method
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE


CDHM Prototype Demo
False Ceiling - 1
LEVEL 4
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE


CDHM Prototype Demo
Misc. Facilities - 1
LEVEL 4
BSE agrees with ?
MS agrees with ?
SE agrees with ?
HM agrees with ?
BSE Drawing
MS Drawing
SE Drawing
HM Drawing
New card
Archive
All agreed ?
Index card
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE


CDHM Prototype Demo
Scope of Improvement works
LEVEL 2
Air conditioning
Vertical transportation
Transformer house
Fire services
Lighting
Signage
Retail space
Finishes
External Facade
False ceiling
Miscellaneous Facilities
Change level
Set User Profile
Level :
Improvement Objective (1)
BSE


CDHA Prototype Demo
System Sizing, Materials & Detail design
LEVEL 4
Air conditioning
Vertical transportation
Transformer house
Fire services
Lighting
Signage
Retail space
Finishes
External Facade
False ceiling
Miscellaneous Facilities
Change level
Set User Profile
Level :
Improvement Objective (1)


CDHA Prototype Demo
BUS TERMINUS
OPEN AREA
MARKET
SHOPS
OPEN AREA
Location 1
OPEN AREA
Location 2
Level :
Improvement Objective (1)

APPENDIX FOUR

APPENDIX 4

Comparison of draft design brief vs. results of prototype CDHM demonstration

Remarks: The prototype CDHM only covers Section 2 (Improvement Objectives) and Section 5 (Improvement Considerations) as other Sections are deemed as standard or background information not directly related to the collaboration process.

Design Brief for Improvement of Fu Shin Shopping Centre

Results of comparison are shown in this column ⇩

1. INTRODUCTION

1.1 Fu Shin Shopping Centre, Tai Po was completed in 1986 as a Type C centre (Large Neighbourhood Centre) presently serving about 34,000 residents (8938 flats) of Fu Shin Estate, Ming Nga Court and Yee Nga Court as its primary catchment area.

1.2 The Centre is a small 3-storey building close to the bus terminus. It provides 1 Chinese Restaurant, 2 fast food shops and 38 shops of limited trades to cater for the daily needs of the residents.

1.3 The market with 86 shopstalls is situated on the G/F of the carpark building adjacent to the centre and is able to attract local and outside patronage within the district.

1.4 The cooked food stalls were located over a separate free-standing terrace (refuse collection point underneath) in a contained environment.

1.5 The commercial facilities and finishes in the centre are inadequate to meet the rising demand of shoppers and is difficult to compete successfully with the private shopping centres in close vicinity to Fu Shin Estate.

2. IMPROVEMENT OBJECTIVES

2.1 To upgrade the facilities of the centre, improve its accessibility, and sustain the competitiveness of the centre. } SHOWN AS STATEMENT IN A COLLABORATION MATRIX

2.2 To provide additional retail space in improving the trade-mix and tenant-mix of } SHOWN AS STATEMENT IN A COLLABORATION MATRIX the centre and market, in order to meet the aspiration of residents.

3. SCOPE OF WORK

3.1 The consultant is required to undertake the following tasks in conjunction with the design work of this improvement project :-

(i) To appraise the existing condition and design of the centre.

(ii) To explore design of new shop premises and means to enhance the space usage.

(iii) To examine ways and means to improve internal circulation and linkage.

(iv) To draw up the scope and proposals of improvement required, recommend the priorities and stages of work together with cost estimates, and a programme for implementation.

(v) To examine the need and advise on the nature of enhancement where required to the existing building finishes (subject to para. 5.3.4) and building services as part of the improvement strategy.

4 BACKGROUND INFORMATION

4.1 The following fact sheet and plans are attached for reference :-

Appendix I	- Location Plan
Appendix II	- Estate Vesting Order Plan
Appendix III	- Estate Layout Plan
Appendix IV	- Estate Particulars
Appendix V	- Floor Layout Plans of the Centre
Appendix VI	- Building Services Technical Requirements

Results of comparison are shown in this column

5. IMPROVEMENT CONSIDERATIONS

5.1 Addition of Retail Space

5.1.1 Addition of retail space should comply with the approved Planning Brief provision. The Housing Department considers it viable to introduce a maximum increase of about 600m^2 (IFA) for Fu Shin Shopping Centre.

① WITH "AGREED" COLLABORATION MATRIX

5.1.2 The proposed additional retail space must be identified within the estate vesting order boundary, otherwise, revision of the vesting order and agreement of other government departments are required.

◇1 STANDARD INFORMATION REQUIRES NO COLLABORATION MATRIX

5.1.3 The consultant should study and propose suitable space for additional retail space, consideration of which may be given to :-

(A) Construction of shops of about 440m^2 IFA by taking down the wall of the centre facing the bus terminus and extending the arcade.

② WITH "AGREED" COLLABORATION MATRIX

(B) Construction of 4 shopstalls of about 16m^2 each next to the storerooms facing the loading / unloading area.

③ WITH "AGREED" COLLABORATION MATRIX

(C) Any other location deemed suitable and viable.

◇2 OPEN-END STATEMENT IRRELEVANT TO CDHM

5.1.4 No central air-conditioning will be provided to new shops. Allowance should be made in the detailed design for installation of air-conditioning units by the tenants.

④ WITH "AGREED" COLLABORATION MATRIX

5.1.5 The power supply of the shopping centre is provided by 2 x 2500A transformers and the maximum demand of electricity of each transformer is about 1200A at present, so there is some spare electricity capacity if scale of improvement is not extensive. However, the consultant may consider the requirement of a new transformer room to cater for the scope of improvement.

1 WITH COLLABORATION MATRIX BUT WITHOUT AGREEMENT

5.1.6 The shops/shopstalls shall be provided with basic facilities according to the Housing Authority's Estate Facilities Design Guide - Commercial Centres, licensing and environmental protection regulations. 3 STANDARD INFORMATION REQUIRES NO COLLABORATION MATRIX

5.1.7 Trade designation and marketing of new shops and shopstalls will be decided by the Commercial Properties Division of the Department. 4 STANDARD INFORMATION REQUIRES NO COLLABORATION MATRIX

5.1.8 The consultant shall seek agreement from and make arrangement with other departments/utility companies for works to be carried out at the bus terminus and for temporary relocation of the bus regulator's office if these are affected by improvement works. 5 STANDARD INFORMATION REQUIRES NO COLLABORATION MATRIX

5.2 **Improvement to Existing Design and Facilities**

5.2.1 To ensure viability of the centre and to cope with the increase of retail space, it is necessary to appraise the existing design and facilities and propose improvement measures wherever required. Area of study will include :-

(A) Vertical Accessibilty

Installation of one additional escalator to improve vertical linkage between G/F and 1/F in the shopping centre at suitable location. 1 WITHOUT COLLABORATION MATRIX

(B) Transformer Room, Switch Room and Meter Room

Construction of new transformer room, switch room and meter room may be considered if required by improvement. Suitable location has been identified near the refuse collection point underneath the cooked food stalls. Consultant may consider other suitable place subject to agreement of the Housing Manger/Fu Shin. 5 WITH "AGREED" COLLABORATION MATRIX

(C) Fire Services Facilities

(i) Replacement of exit/smoke doors in the shopping centre. Consultant should appraise the fire compartmentation and means of escape to comply with current fire safety standard. } (2) WITH COLLABORATION MATRIX BUT WITHOUT AGREEMENT

(ii) Provision of F.S. installations to new shops/shopstalls. } (3) DITTO

(D) Finishes

(i) Renovation of the external facade of the shopping centre and the market cum carpark building. } (6) WITH "AGREED" COLLABORATION MATRIX

(ii) Replacement of false ceiling in the shopping centre. } (7) DITTO

(iii) Replacement of parapets at the three voids of 1/F arcade in the shopping centre. } (8) DITTO

(iv) Touch-up works to the railings in the centre. } (9) DITTO

(E) Lighting

Improvement of lighting to the shopping centre. } (10) WITH "AGREED" COLLABORATION MATRIX

(F) Signage System

Provision of external signages and renewal of internal signages, directories and suspended shop signs to tie in with new false ceilings. } (11) WITH "AGREED" COLLABORATION MATRIX

5.2.2 Apart from the above, other facilities which are considered necessary as part of the main scope of improvement or statutory required may also be explored and introduced. } (6) STANDARD INFORMATION REQUIRES NO COLLABORATION MATRIX

5.3 **Scope of Work Not Intended**

5.3.1 Provision of central air-conditioning to existing shopping centre, market, and new shops is not intended. (12) WITH "AGREED" COLLABORATION MATRIX

5.3.2 General improvement inside the market shall not be covered by this improvement project unless affected by future improvement design. (2) WITHOUT COLLABORATION MATRIX

5.3.3 Improvement to cooked food stalls and carparks shall not be covered by this improvement project unless affected by future improvement design. (13) WITH "AGREED" COLLABORATION MATRIX

5.3.4 Whole scale replacement of existing floor and wall tile finishes in the centre is not necessary unless considered required to tie in with other improvements. (14) WITH "AGREED" COLLABORATION MATRIX

6. **STRUCTURAL CONSTRAINTS**

6.1 The Consultant, when designing any new foundation, shall pay due attention to the existing poor subsoil conditions and the low soil bearing capacity.

6.2 As revealed in the latest ground investigation report, the area concerned is overlain by Fill (0-6m), Marine Deposit (6-19m), Alluvium (19-25m), Decomposed Tuffaceous Sandstone (25-53m) and Grade III Tuff (below 53m).

6.3 Because of the existence of the Soft Marine Deposit at the site, it is recommended that the allowable bearing pressure for shallow footing be not more than 40kPa. Besides that, the Consultant shall also have to pay due consideration to the possible undue settlement encountered. The above-mentioned Ground Investigation Report can be obtained on request from the Department.

Summary of comparison:		
	(14)	WITH "AGREED" COLLABORATION MATRIX
	(3)	WITH COLLABORATION MATRIX BUT WITHOUT AGREEMENT
	(2)	WITHOUT COLLABORATION MATRIX
	(6)	STANDARD INFORMATION REQUIRES NO COLLABORATION MATRIX

7 OVERRIDING CONDITIONS

7.1 The design shall be checked and certified structurally feasible by a registered structural engineer sub-consultant appointed by the consultant prior to submission. The RSE has to check the adequacy of the existing structure in sustaining the new/modified loads, if any, to the code in force at the time of original design. Any modification which will lead an existing structure to a deficient critical state by current design standard shall not be permitted. Extensive or complicated foundation work or diversion of underground/essential services should be avoided.

7.2 In the case a new structure arises, the design shall comply in all aspects to the current British Standard and with the relevant ordinances/regulations/rules currently enforced by other government departments and public bodies such as Building Department, Fire Services Department, Environmental Protection Department, etc.

7.3 Design for building services shall be checked and certified by a qualified building services engineer sub-consultant appointed by the consultant prior to submission to the Housing Department and shall comply with the technical requirements at <u>Appendix VI.</u>

7.4 Consideration should be taken in the designed implementation of improvement works to minimize disturbance to the sitting tenants and shoppers.

7.5 An environmental impact study should be carried out at scheme design stage and measures to mitigate nuisance should be proposed.

7.6 The consultant is required to :-

(i) Assist Staff of Housing Department in briefing tenants, resident representatives, local dignitaries, etc. of the improvement scheme.

(ii) Deal with complaints arising from implementation of works and site management; and

(iii) Give technical advice on tenant's fitting-out proposal and make recommendation to the H.D. for consideration during construction period.

8. **COST CEILING**

8.1 The project construction cost shall not exceed $____million unless otherwise approved by the Director or the Director's Representative.

9. **PROGRAMME**

9.1 Project period including design and approval from all necessary government department shall not exceed 36 months, within which 18 months will be the preferrable works period.

9.2 The overall programme should take into consideration of the lead time necessary for submission of scheme to relevant committees and contract tender arrangement.

10. **INSTRUCTION AND MANUAL TO FOLLOW**

10.1 The following instructions, manuals and drawings shall be provided to the Consultant after appointment:

(i) Housing Authority's Estate Facilities Design Guide-Commercial Centres.

(ii) Signage Manual for Commercial Centres of Public Housing Estates.

(iii) Architectural Drawings of Shopping Centre.

(iv) Structural and Building Services Plans.

(v) Drawing Practice Manual.

10.2 The Consultant should note that drawings and plans of the existing shopping centre may not be complete and readily available and the consultant is expected to verify on site all information provided by the H.A.

APPENDIX FIVE

APPENDIX 5

Listing of HyperTalk script developed in CDHM

Remarks: In CDHM, HyperTalk scripts have been written and attached to different HyperCard objects such as buttons, fields, cards and card background. The main purpose is to realize those specific functions identified in the analysis of the collaboration process, such as locking fields for concurrency control, checking agreement, creating new components of CDHM, etc. Regarding the definitions, meanings and syntax of HyperTalk commands and functions, reference should be made to the Script Language Guide of the HyperCard manual. The listing below is not exhaustive; scripts of buttons for browsing and navigation are not included.

Background script

Purpose: **to denote project identity by placing project name in the "Project Name Field" (Figure 31).**

```
on closeCard
 if number of this card is 1 then
  select text of cd fld ID 1
  put the selectedText into background fld ID 6
 else pass closeCard
end closeCard
```

Field script in Interface card for logging in user identity

Purpose: to denote identity of PT member by placing PT member identity in Identity field (Figure 30).

```
on mouseUp
 put the selectedText of cd fld 1 into it
 get word 1 of it
 if it is empty
 then exit mouseUp
 else put it into bg fld 3
 if it is bse then answer "I am BSE."
 if it is ms then answer "I am MS."
 if it is se then answer "I am SE."
 if it is hm then answer "I am HM"
 if it is adm then answer "I am ADM"
 --go next
end mouseUp
```

Field script in Interface card for choosing design level preference

Purpose: to denote design level chosen by PT member by placing the choice in Design Level field.

```
on mouseUp
 put the selectedText of cd fld 1 into bg fld 2
 get word 1 of bg fld 2
 if it is empty then exit mouseUp
```

```
  if it is improvement then go cd "objective"
  if it is major then go cd "proposal"
  if it is scope then go cd "scope"
  if it is system then go cd "system"
end mouseUp
```

<u>Card script to lock field (collaboration matrix)</u>

Purpose: **to lock or unlock field of collaboration matrix according to the Identity field status (Figure 29).**

```
on openCard
  get  word 1 of cd fld 6
  if it is not archived then dolockfield
  else doArchived
  pass openCard
  domenu "redraw screen"
end openCard

on doArchived
  set enabled of cd btn 13 to false
  get word 1 of bg fld 3
  if it is adm then set enabled of cd btn 13 to true
  else exit doArchived
end doArchived

on dolockfield
  set locktext of cd fld 1 to false
```

```
  set locktext of cd fld 2 to false
  set locktext of cd fld 3 to false
  set locktext of cd fld 4 to false
  set enabled of cd btn 2 to true
  set enabled of cd btn 4 to true
  set enabled of cd btn 5 to true
  set enabled of cd btn 6 to true
  set enabled of cd btn 13 to false
  get word 1 of bg fld 3
  if it is bse then doBse
  if it is ms then doMs
  if it is se then doSe
  if it is hm then doHm
  if it is adm then doAdm
  else exit dolockfield
end dolockfield

on dobse
  set locktext of cd fld 2 to true
  set locktext of cd fld 3 to true
  set locktext of cd fld 4 to true
  set enabled of cd btn 4 to false
  set enabled of cd btn 5 to false
  set enabled of cd btn 6 to false
end doBse

on doMs
  set locktext of cd fld 1 to true
```

```
  set locktext of cd fld 3 to true
  set locktext of cd fld 4 to true
  set enabled of cd btn 2 to false
  set enabled of cd btn 5 to false
  set enabled of cd btn 6 to false
end doMs

on doSe
  set locktext of cd fld 1 to true
  set locktext of cd fld 2 to true
  set locktext of cd fld 4 to true
  set enabled of cd btn 2 to false
  set enabled of cd btn 4 to false
  set enabled of cd btn 6 to false
end doSe

on doHm
  set locktext of cd fld 1 to true
  set locktext of cd fld 2 to true
  set locktext of cd fld 3 to true
  set enabled of cd btn 2 to false
  set enabled of cd btn 4 to false
  set enabled of cd btn 5 to false
end doHm

on doAdm
  set locktext of cd fld 1 to true
  set locktext of cd fld 2 to true
```

```
set locktext of cd fld 3 to true
set locktext of cd fld 4 to true
set enabled of cd btn 2 to false
set enabled of cd btn 4 to false
set enabled of cd btn 5 to false
set enabled of cd btn 6 to false
set enabled of cd btn 13 to true
end doAdm
```

<u>**Pop-up button script**</u>

Purpose: to facilitate the quest for agreement (Figure 32).

```
on mouseUp
 -- choice botton for BSE
 put the selectedText of btn 2 into it
 if It is ms then  put cd fld 2 into cd fld 1
 if It is se then  put cd fld 3 into cd fld 1
 if It is hm then put cd fld 4 into cd fld 1
 else exit mouseUp
end mouseUp
```

"Archive" button script

Purpose: **to archive a collaboration matrix**

```
on mouseUp
  answer "Do you want to archive design records?" with "No" or "Yes"
  if it is "Yes" then doFreeze
  else if it is "no" then put empty into cd fld 6
  exit mouseUp
end mouseUp

on doFreeze
  put "ARCHIVED" into cd fld 6
  get word 1 of bg fld 3
  if it is bse then doBse
  if it is ms then doMs
  if it is se then doSe
  if it is hm then doHm
  else exit doFreeze
end doFreeze

on doBse
  set locktext of cd fld 1 to true
  set enabled of cd btn 2 to false
end doBse

on doMs
  set locktext of cd fld 2 to true
  set enabled of cd btn 4 to false
```

```
end doMs

on doSe
 set locktext of cd fld 3 to true
 set enabled of cd btn 5 to false
end doSe

on doHm
 set locktext of cd fld 4 to true
 set enabled of cd btn 6 to false
end doHm
```

<u>"All agreed?" button script</u>

Purpose: to facilitate PT members in reaching agreement.

```
on mouseUp
 put cd fld 1 into bse
 put cd fld 2 into ms
 if bse = ms then
  checkSe
 else answer " no agreement."
end mouseUp

on checkSe
 put cd fld 1 into bse
 put cd fld 3 into se
 if bse = se then
```

```
    checkHm
  else answer "no agreement."
end checkSe


on checkHm
  put cd fld 1 into bse
  put cd fld 4 into hm
  if bse = hm then
    play "harpsichord" tempo 200 "ce4 fe ae c5q ae4 cq5"
    answer "Agreed!"
    put "AGREED!" into cd fld 7
  else answer "no agreement."
end checkHm
```

"New card" button script

Purpose: **to facilitate ADM to create new card either collaboration matrix or index card.**

```
on mouseUp
  domenu "copy card"
  domenu "paste card"
  put empty into cd fld 1
  put empty into cd fld 2
  put empty into cd fld 3
  put empty into cd fld 4
  put empty into cd fld 6
  put 1 into var1
```

```
 put var1 + 1 into cd fld 5
end mouseUp
```

Card script to lock field (index card)

Purpose: to lock or unlock field of index card for maintaining concurrency control.

```
on openCard
 set enabled of cd btn 1 to false
 put 2 into i
 repeat with i = 2 to 21
  set locktext of cd fld i to false
 end repeat
 get word 1 of bg fld 3
 if it is not hm then doLockfield
 if it is adm then set enabled of cd btn 1 to true
 else pass openCard
 domenu "redraw screen"
end openCard

on doLockfield
 put 2 into i
 repeat with i = 2 to 21
  set locktext of cd fld i to true
 end repeat
end doLockfield
```

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REFERENCES

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Hypermedia and engineering design

John D. Gilleard and Y.C. Lee
Department of Building Services Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

Building Services Engineering (bse) is an applied discipline within the construction industry. It is concerned with the design, installation, operation and maintenance of all mechanical and electrical systems in buildings. Design software developed for the bse industry is typically structured on sets of well established rules and building codes. Anecdotal evidence indicates that junior designers, who may lack experience and confidence, frequently adopt a 'black box' approach when applying design software. This may be contrasted with the more experienced designer who typically questions the assumptions and algorithms adopted before applying the programs. However, this is not always possible even for the experienced designer, particularly where 'conventional' computer-languages have been used to develop the software. It is therefore argued within the paper that for some applications design software based on hypermedia may be more appropriate. This is demonstrated through the development of a prototype 'fire sprinkler layout design' model using HyperCard. The paper also indicates that by constructing strategic relations between objects the effectiveness of the design model can be enhanced. In this way the designer is better able to control the process of navigation within the model.

1. Introduction

It has been shown that a design tool for rule-based building services engineering (bse) design is appropriate using hypermedia as the authoring mechanism.[1] The argument was supported by the construction of a HyperCard model for 'fire sprinkler layout design' based on a set of safety rules and codes.[2] These rules are a combination of the revised British Standard BS 6306: Part 2: 1990 and the Technical Bulletins issued by the Loss Prevention Council (LPC) of the UK.[3]

A prototype fire sprinkler design model (LPC model) identified that the relationships between objects, defined as chunks of information embedded in the design rules, were sequential in nature. That is, they mimicked the pattern established within the formal LPC Rules document. However, under evaluation experienced bse designers questioned the need for the LPC model to be so prescriptive, arguing that the method was too mechanistic. These designers stated that more typically the design process was one based on trial and error, with much 'looping' between possible solutions. Consequently, the adoption of a formal system based on rigid rules seemed to be counterproductive. Therefore the early LPC model was revised in order to identify the critical relations between objects or rules.

2. Effectiveness of information retrieval and relation definition

The main concern for the further development of the LPC model was to increase the value of the model by improving the effectiveness of navigation against a specific target, i.e., to retrieve the right card in the shortest possible time. The ability to recall retrieved information and the relevance of the retrieved information were also deemed to be critical considerations when judging the effectiveness of model. This corresponds to the common understanding that the effectiveness of conventional retrieval systems are limited by an unavoidable trade off between the two standard measures of effectiveness, i.e. between precision and recall.[4] Typically, users are frequently required to browse through a large amount of data before they find relatively small quantities of useful information. To address this type of problem, previous hypermedia design software typically alerts the user to any specific design criteria he should consider prior to making any final decision.[5] In addition, for an issue-based hypertext system, every design question is counted as an issue linking to other issues or it is a design question with the so-called 'serve relationship'. In this case the resolution of one issue influences the resolution of another issue and 'subissue of' is the main serve relationship. Such a hypertext database may form a quasi-hierarchy of issues with subissues similar to a tree-like structure.

Defining relationships between objects of a data model in a hierarchical form (or semantic structure) has received much attention. (With an increase in the complexity of data models the need for a classification system that clearly defines the relations between data may be said to be unavoidable.) Definition and classification for data objects are being pursued in at least three areas of research in the construction domain, e.g., 'building-by-building product modelling',[6] 'construction technology/method identification and selection system', (CTIS),[7] and 'classification system to extract project-specific building codes'.[8]

It has been suggested that standardized product modelling of buildings (or more strictly their components) offers a solution for the integration of CAD-based systems with knowledge-based systems. Product models are conceptual structures that specify what kind of information is used to describe buildings and how such information is structured. The methodology used in these models is object-centred and based on advanced concepts in database software, knowledge-based systems and programming language theory. The central concepts are objects, attributes and relationships between objects. These building objects, such as rooms, walls, heating equipment, etc., are described in various ways, e.g., conceptual (using attribute data), graphical and textual windows. During the construction of a building model it is necessary to add standard types of relationships between objects. Attribute types of objects may to some extent be found in standard construction specifications, but the classification of different kinds of relations is considered to be a totally new area, in which research is only starting. A gradual implementation of steps in defining a product model standard may be identified, figure 1.

A CTIS helps to provide the required technology information for design and construction planning decisions, in a manner that supports the changing needs during the various design and construction stages. Conventional models, such as the network data model and the relational data model, are based on flat data structures which are well suited for homogeneous data types. These, however, do not have sufficient semantic expressive function to describe the relationships of entities. More appropriate is the use of the semantic data models which essentially are the definitions of objects and the relationships between objects. The information about constructed products, materials, methods, equipment are held in various stacks, e.g., cards in a HyperCard model. Each card in a stack contains a chunk of different information and represents a different object. Links representing different defined relationship between objects are implemented via buttons. A simplified structure of the model is shown in figure 2.

The vision of a classification system to extract project-specific building codes is to provide an electronic building code for code users demanding automated solutions, and sophisticated users interested in the integration of code information with other computer application such as CAD. Definitions of the codes are developed into concepts which are linked by different types of relations to form a classification schema. Clearly, a different knowledge base requires different definitions of relations between information objects, as well as the classification systems for the relations defined at various level of sophistication. As such, the semantic structure of the first LPC Rules model was evaluated with a view to constructing significant relations and their classification, which may be able to tally with the specific semantic structure of the model.

3. Identification of relations in the HyperCard LPC Rules Model

The sequential relations defined in the first LPC Rules model were generally represented by the main menu, figure 3, where the design subprocesses and the detailed design information carried by them were placed into various cards and stacks. These were seen as objects and linked by appropriate buttons. Although figure 3 implies a flow or sequence within the design model there is no obvious order between these six stacks. The exception to this general condition is the need to declare 'the class of hazard' early on in the design process (The

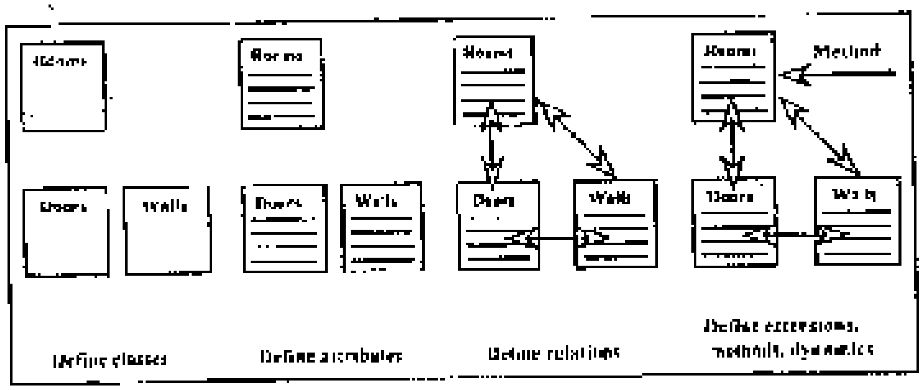

FIG. 1: *Gradual implementation steps in defining a product model standard*

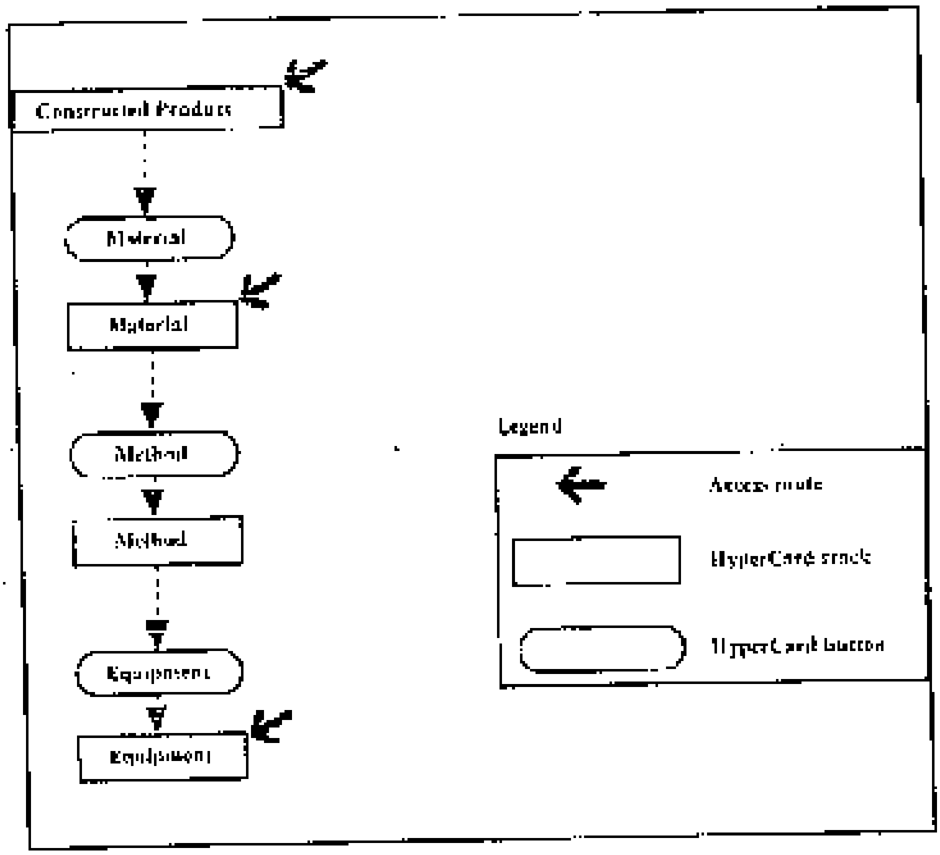

FIG. 2 *The simplified structure of the CTIS prototype*

requirements for fire sprinkler layout design are categorized under different 'classes of fire hazards' in the LPC Rules.) Therefore, the original flow chart (which serves as the main menu) was subsequently modified, figure 4, in order to reflect the freer choice that the user now has when locating design specific information. However, the classification of fire hazard still acts as a focus for all links between the various objects, i.e. subprocess stacks, cards, etc.

Typically, only one unconditional relationship between any two cards exists. However, links among various arguments of the LPC Rules may also be abstracted using other relations, the three most frequently used being:

- 'and then' relation which provides a sequential path between two cards;
- 'see also' relation which offers a side reference for illustration purposes;
- 'if then' relation which requires the user to impose certain condition before moving to the next card.

In fact all three relations form a part of the first LPC Rules model. The first two are available in an interactive form created by using a direct HyperCard function for building links with buttons. The 'if then' relation requires the user to answer questions regarding a decision resulting from a previous navigation and which the user may not readily remember.

Classification of relations for the model is not a simple task as it is difficult, although not impossible, to exhaust all the relations which are not explicitly defined in the original LPC Rules. The Rules in their literal form may not require such a classification system. (The interpretation of building codes, such as the LPC Rules, are frequently left to the deliberation of the user.) Where the rules are not explicit this requires judgement on the part of the user. Although it is possible to determine 'best practice' guidelines clearly it is not possible to extrapolate all possible decisions that a user may take.

4. Construction of relationships within the LPC model

The 'and then' relation is the simplest link to build. Using standard functions under the 'button' mode, this relationship may be developed without carrying out any extra programming. The link 'and then' is used for navigation from one card to another card or to another stack. It is most commonly found on cards with graphical displays providing the user with various options. For example, the main menu card shown previously, figure 4, indicates that the user is required to select one of six options in order to move forward with the design. This is a logical step in the design process. Basically, cards carrying chunks of information in a logical order are deemed as objects connected by this type of relation.

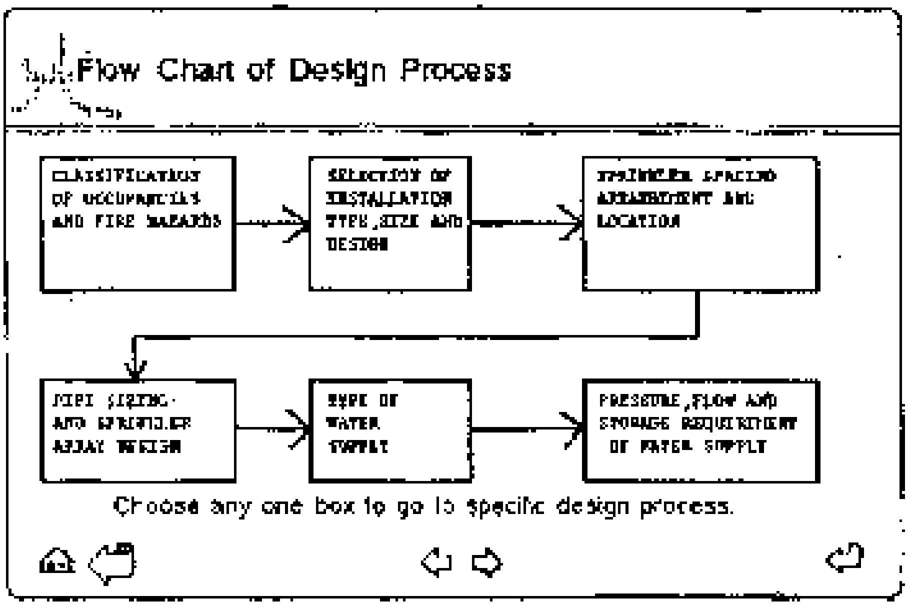

FIG. 3: *Six design subprocesses defined as main menu*

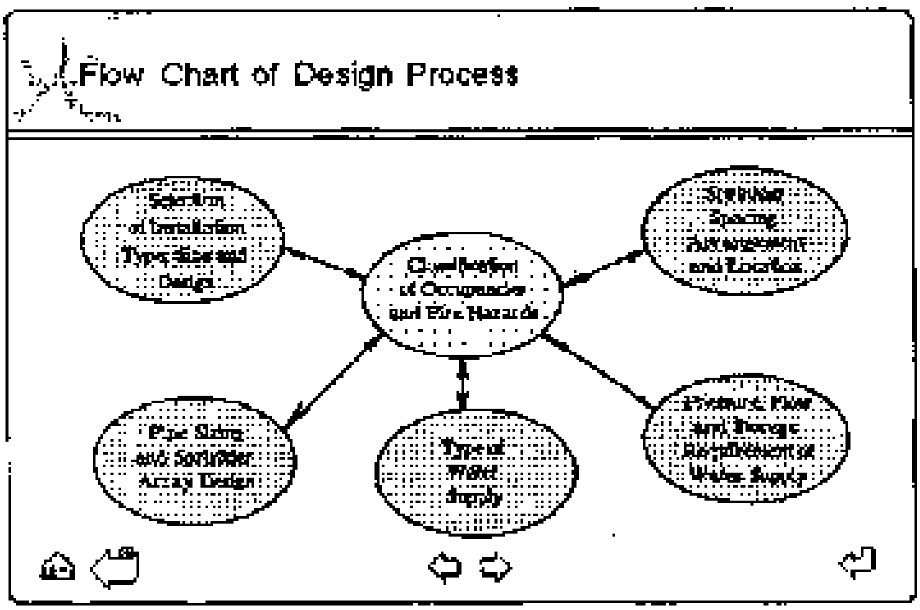

FIG. 4: *Modified main menu showing Classification of Fire Hazard as focus of navigation*

Linking a card to an external graphic file is an example of the 'see also' relation. This is implemented by clicking of a button which has been programmed to open a graphic file outside the LPC Rules model. While the external graphic file is open, the user cannot make any change to it because the application software remains inactive. Browsing of other card is also prohibited unless the user returns to the card where the graphic file has been launched. In this case, a card and an external graphic file are the two objects linked by this relationship. This is bi-directional only and any side tracking will not be viable.

'And then' and 'see also' relationships do not require any detailed planning of the data structure for implementation, and only two objects are involved at any one time. They may be seen as the result of the natural expression of the requirements in the LPC Rules undergoing a transformation in the HyperCard environment. On the other hand, the 'if then' relation represents a much more complex mapping operation among several objects at the same process. The purpose is to provide a mechanism to guide the subsequent navigation according to certain preset conditions, where a previous decision has been made by the user.

Before starting any HyperTalk programming (HyperCard's programming language) to create a link for the 'if then' relation, a number of questions have been raised:

- What are the objects to be linked by this relation?
- Will the 'if' condition be treated as an object?
- What are the 'if' conditions that need to be considered? and
- Is the 'if then' relation over-simplified in representing several chunks of information which should be manifested in a more complex algorithm?

While there may not be straightforward answers to these questions, the scope of the problem can be narrowed down by confining the navigation paths to achieve the 'recall' function only, which has been noted as the major limitation of the first LPC Rules model. Under such circumstances, there are at least three objects involved in an 'if then' relation when implementing the 'recall' function:

- The current active card that contains options of choices.
- The conditions previously determined by the user ready for interrogation.
- The card that contains the resultant information consistent with the condition.

Depending on the number of conditions recorded in an earlier navigation, the number of objects connected by this relation may multiply, figure 5. Therefore, in order to avoid conceptualizing the issue of relation

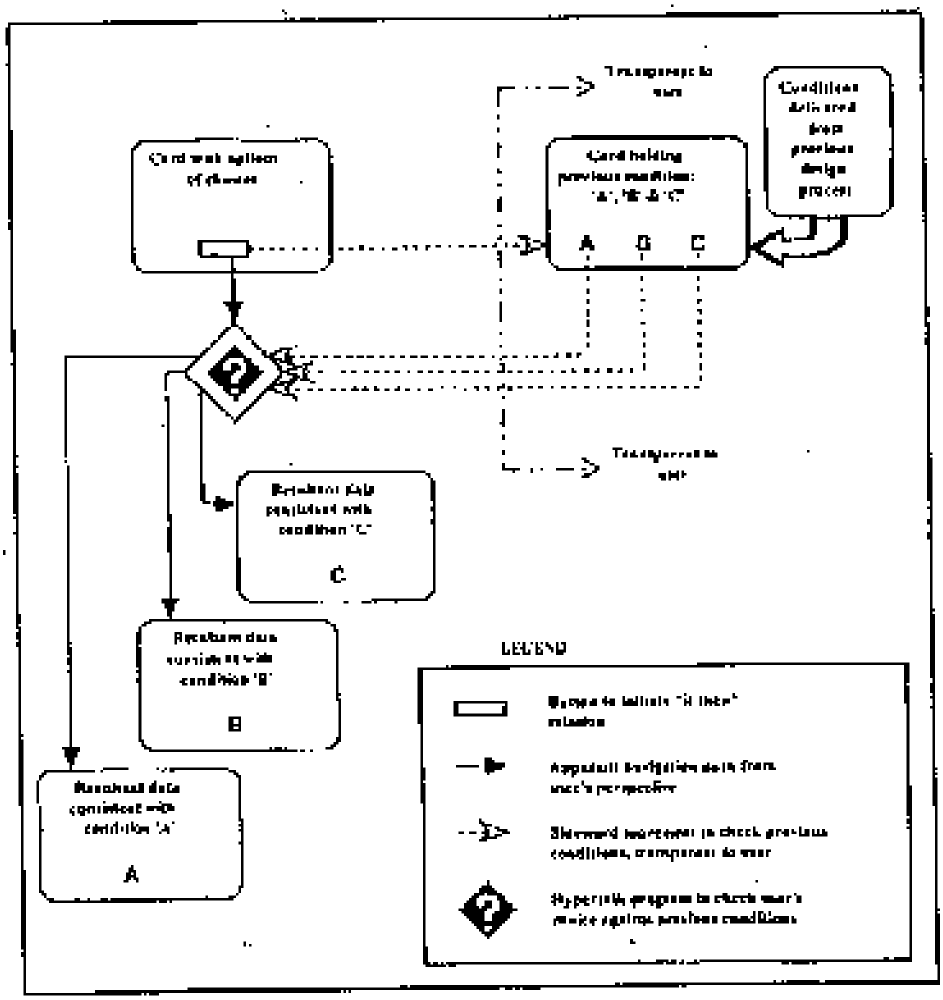

FIG. 5: *Principle of the 'recall' function as derived from the 'if then' relation*

further, the subsequent development work has focused on the more essential 'if' condition that affects all of the design subprocesses. It is therefore argued that through proper structuring of the objects in the HyperCard model, the user may recall his choice of 'class of fire hazards' in his earlier navigation and proceed in a much smaller hyperspace, thus improving the effectiveness for retrieving design specific information. It may also be demonstrated that the approach adopted takes up less computer memory space by virtue of a simpler data structure.

There are three main classes of fire hazard, i.e., Light, Ordinary and High. Each of these lead to a different set of information which, although similar in format and presentation, are distinct. For example, requirements of different class of hazards may appear in the same table. Using the automated 'if then' relation will require the creation of only one table duly shared by the three classes of hazard. Otherwise, it

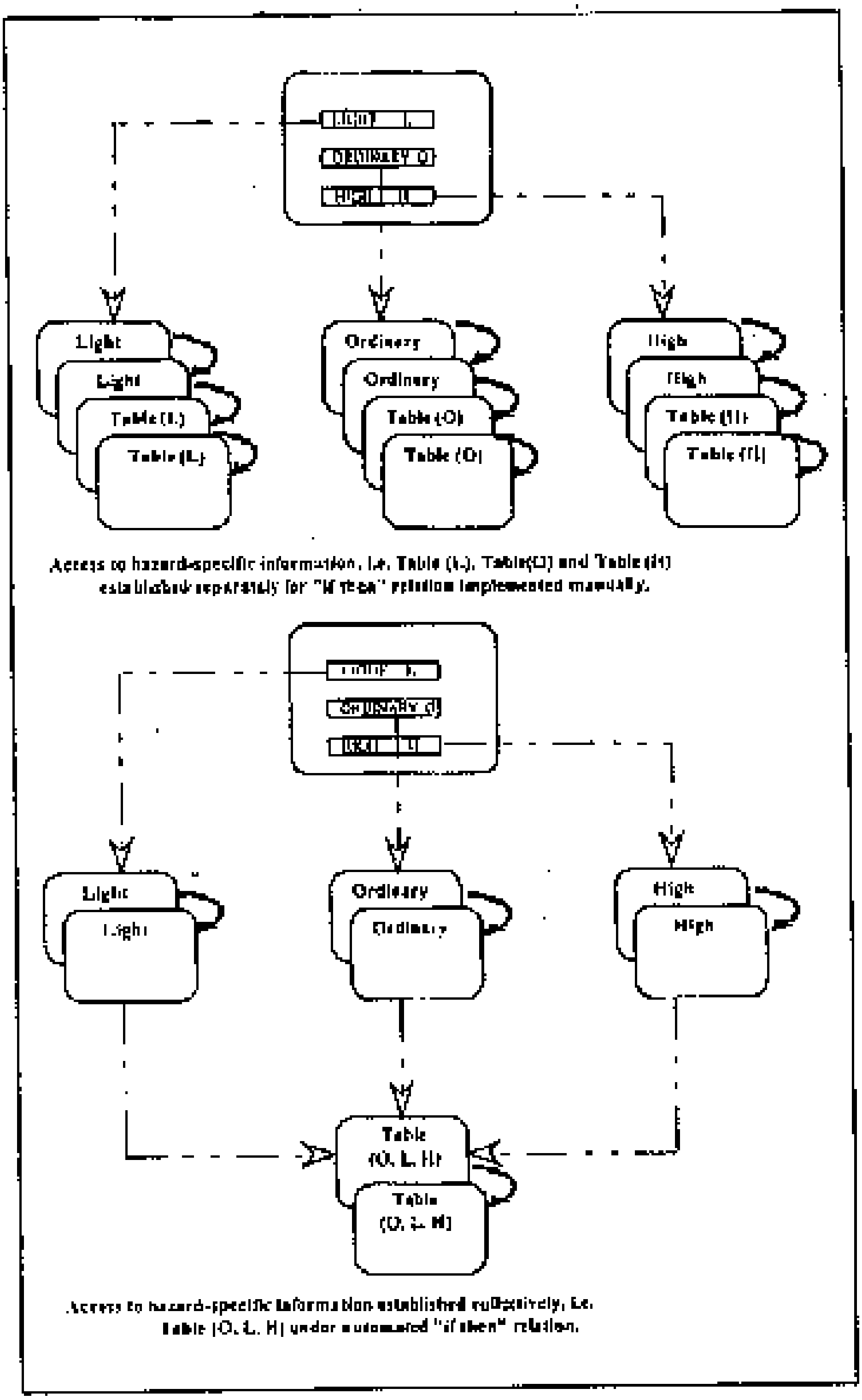

FIG. 6: *Automated 'if then' relation requires less computer space*

would need three separate tables placed under the three respective classes of hazards, figure 6.

Firstly it is necessary to provide the facility for the user to capture and record the 'if' condition so determined while working with the design subprocess for the 'Classification of Occupancies and Fire Hazards', i.e., Light, Ordinary Hazard or High Hazard. A separate card (hazard card) is created in the same stack to carry the chosen class of hazard. This is subsequently transferred from the card that concludes the interrogation of fire hazards via a button that has been embedded with the necessary script for this particular action. The hazard card may thus be considered to act as a buffer zone to store the user's choice. This may be updated at any time. It is unique in comparison with all other cards in the LPC Rules model as far as its function and operation are concerned, i.e. it does not carry any static information and it is not visible to the user under normal situations.

During subsequent navigations, whenever the user indicates his choice of fire hazards, the program will retrieve the hazard card to see what has been specified and advise the user whether he is correct or not before jumping to the next card pertinent to the 'then' relation. For any choice that is in line with the 'if' condition, the next appropriate card will be displayed as if nothing has happened. In case the user has made an inconsistent selection — prompted by an error message — he may override the preset hazard or simply reset it. Such flexibility is essential because it maintains the fluidity of the LPC Rules model without restricting the freedom of choice. The checking function is realized by attaching a button to each 'option of hazard class' (Clicking one class will allow the user to temporarily leave the current card and go to the hazard card to 'see' the previously specified class of hazard).

This recall function has been implemented in the design subprocess of 'Selection of installation type, size and design', shown diagrammatically in figure 7. It can be seen that the 'if then' relation is constructed by two separate HyperTalk programs with the hazard card acting as the point for exchange of information. The first program may be started by clicking the button called 'hazard-based'. This appears in any of the cards showing a specific class of hazard in the 'Classification of occupancies and fire hazards' stack. The second HyperTalk program which is attached to another stack reads the result of the first program whenever the user selects a particular class of hazard. The interrogation process is made transparent to the user by freezing the screen display until the second program has found the answer. Since these two programs belong to two different stacks, the interrogation time is noted to be longer when compared to those within the same stack.

The 'if then' relation may also be applied to any part of the

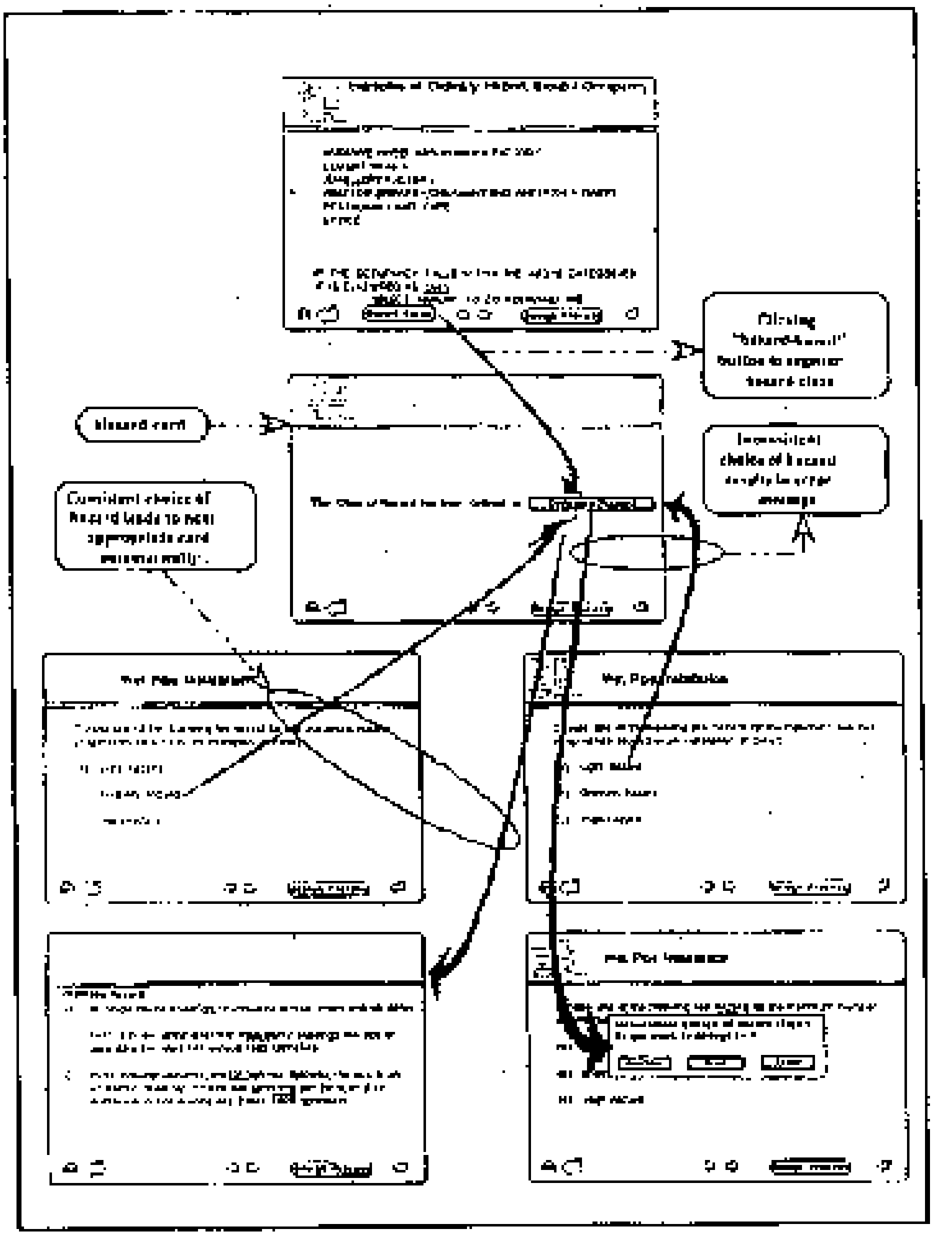

FIG. 7 *The 'if then' relation implemented with the 'hazard card'*

LPC Rules model in order to reduce the number of options later when reviewing the navigation path. However, striking a balance between fluidity of the hypermedia model and a fully automated navigation cannot be overlooked. Typically, it is possible to stop the user from browsing other subprocesses if no class of hazard has been specified in order to emphasize the importance of the classification of hazards. However, unless the prospective user is totally naive, the excessive application of this technique may render the model sluggish and hence undermine the effectiveness of retrieving design specific information as a whole.

In other words, if the user is allowed to have more control in altering navigation paths, i.e., 'authoring', the resulting model may become unduly complicated, leading to much confusion to the user rather than providing guidance.

The application of the 'if then' relation in the 'Selection of installation type, size and design' subprocess demonstrates the case where the user can exercise his own judgment to lock on to a certain criterion. An unrestricted use of this technique has been demonstrated to reduce the effectiveness of the model. However, when the 'if' condition is imposed not by the user but by the model, subsequent navigation is made simpler. In this case it is considered worthwhile to build such links, i.e., when the 'if then' relation is applied in a passive manner with respect to the user.

With the LPC Rules there are cases where the number and type of information items carried in a node is more than the user can manage. In particular this is evident when it is necessary to transfer information to external applications such as a CAD program, e.g., the user may not readily remember which item has been exported. As such, an 'if' condition may be defined so that information that has been transferred and recorded in an external file may be recalled. (Logically, the 'then' should either remind the user what he has already done or simply prevent him from repeating the same path).

This technique has been applied in the 'Sprinkler spacing arrangement and location' stack where the various sprinkler spacing criteria are represented graphically, figure 8. In this case the user may start his searching by clicking the buttons until the card showing the dimensions has been retrieved. Whenever the 'transfer template' button is clicked, the geometrics embracing the dimensional requirement of the sprinkler layout arrangement are copied and transferred to a SuperPaint file. Concurrently, a message is sent to temporarily disable the button that has launched this particular search, i.e. button '1' in figure 8. This button will be re-activated when the user exists and subsequently returns to this stack. During this operation, the HyperCard model is forced to discard some of its nodes (those cards arising from button '1' in this case) and the user has no direct control to stop it from 'losing its memory'. This feature is useful when the sprinkler designer has to repeat similar procedures when designing or checking sprinkler layout drawings, e.g., it will ensure all the criteria have been exhausted. To further facilitate the user to identify the status of a button more readily, the icon of a button is dimmed while it is disabled.

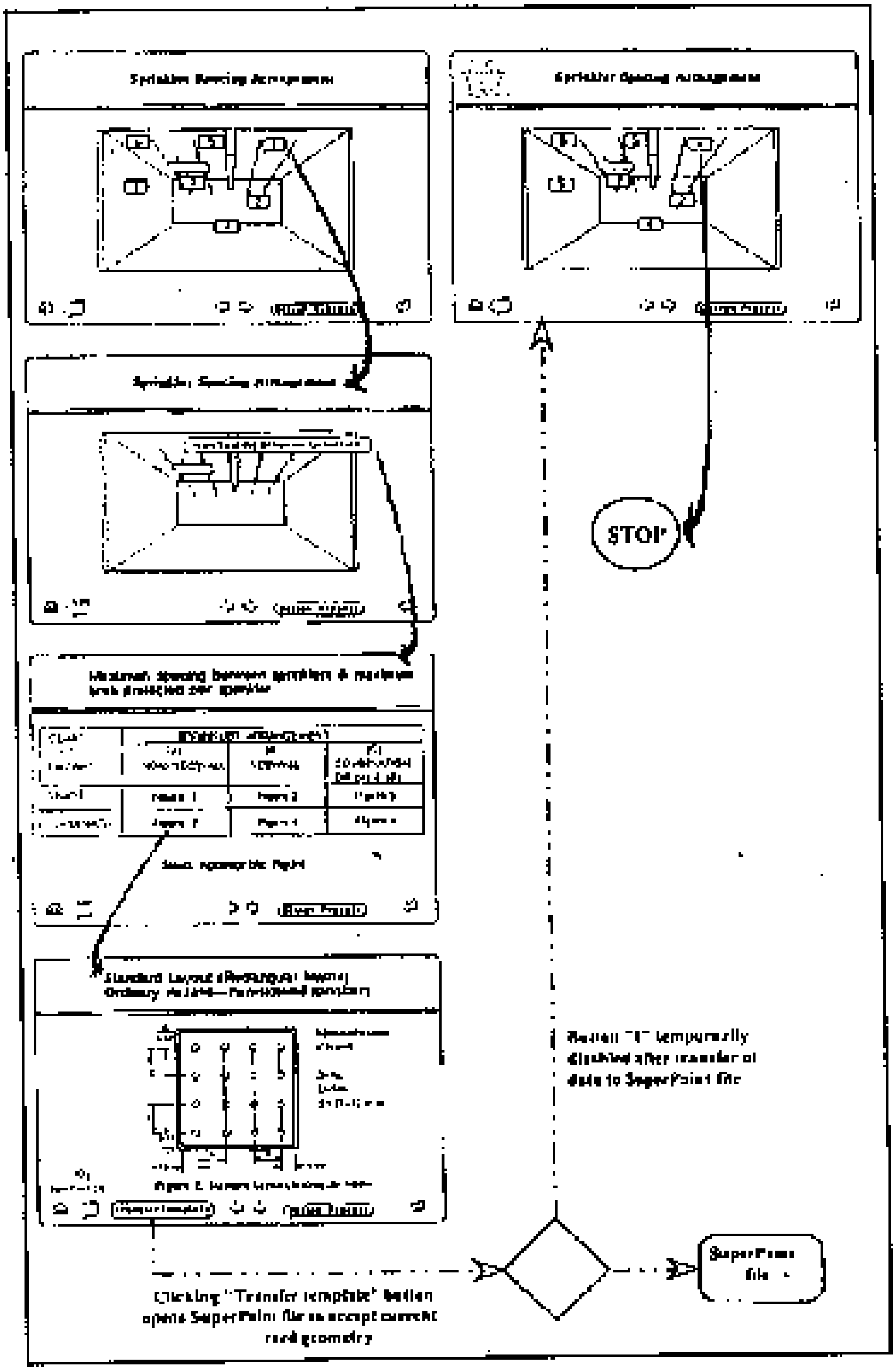

FIG. 8: *Button '1' being 'disabled'*

5. Enhancement of the LPC Rules model based on a conceptual relations approach

For the three types of conceptual relations defined, only the 'if then' relation contributes to the creation of the 'recall' feature. 'And then', 'see also', and 'if then' belong to two totally different classes of relations in that the first two are natural relations while the last one is a forced relation made to satisfy a purpose at the will of the user. The forced relation can result in a slight modification to the data structure. The most consequential purpose of the 'if' condition so far defined is the classification of fire hazard, which has to be taken into account throughout the entire LPC Rules in the acquisition of sprinkler design information. This may be adopted as a standard algorithm to provide express access to answer a user's enquiry.

In summary, with the introduction of 'recall' functions developed on a system of conceptual relations, the user is able to orientate his navigation according to a specific class of hazard while he is still absolutely free to retrieve information about other classes of hazard.

6. Discussion

BSE design is thought to be a 'semi-structured' process. In their recent research, Zachariah and Eames[9] considered that design computing should be carried out in such a manner that the designer may retain control over design and calculation procedures, rather than relying on 'black box' type software. They further suggested that the 'parametric' nature of bse makes it imperative that bse design software should provide facilities for relatively quick 'what if' type of analysis. (They illustrate their arguments by reference to a heating, ventilation and cooling problem. However, their arguments could equally apply to the design of fire sprinkler layouts.)

Clearly hypermedia is a favourable environment to facilitate the development of design software for which is more 'controllable' by the user. The 'if then' relation (as demonstrated in the LPC Rules model) allows the designer to critically examine and question strategic relationships between data/information embedded within the specialist knowledge base. However, direct conversion of the Rules into a hypermedia document does not provide adequate clues in order to ensure that the user retrieves the correct design information. Re-arrangement of the design requirements in a non-lineal manner helps the bse to more easily interrogate the formal rules, and to more effectively explore strategic design information embedded with the document. Navigation aids were found to be paramount to assist users (particularly those new to the LPC model) locate their position when disorientated. In addition, the effectiveness of exploring information was found to hinge on the strategic design of nodes and links. Consequently, intelligent links for cross-referencing and automated criteria checking; alternative paths for experienced and non-experienced users; and graphical display and the transformation of data tables into a more dynamic format were introduced. The ability of the LPC model to recall choices previously made, and to determine implied decisions, also helps the user. Lastly, by linking the design information (generated within the LPC model) to CAD software, the design-decision making cycle was significantly improved.

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(Focus Symposium, August 19th)

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Design and Construction Institute
College of Architecture and Environmental Design
California Polytechnic State University
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SESSION 4: Building Simulation and Reconstruction

Collaborative Design in Building Services Engineering

Lee Yan-chuen and John D. Gilleard

Department of Building Services Engineering
The Hong Kong Polytechnic University

Abstract

Building Services Engineers (BSE) employed by the Hong Kong Housing Authority (HKHA) are responsible for the design, installation, operation and maintenance of all mechanical and electrical (m&e) systems associated with HKHA developments. This work entails the development of the design brief, liaison with the project architect and structural engineer as well as co-ordination of the procurement, delivery and installation of the building services systems. In addition, the BSE is also involved in the operation and maintenance work of the m&e facilities. The work of the HKHA BSE may thus be described as multifaceted, requiring skills of negotiation, co-ordination and design.

In this paper it is suggested that hypermedia is an appropriate paradigm to model the work of the HKHA BSE. By adopting a collaborative design approach, in particular by using synchronous vs. asynchronous and active vs. passive modelling, the paper presents, as a case study, the work involved in the refurbishment of a large shopping centre managed by the HKHA. (The HKHA operates a significant number of major shopping centres within housing estates. These housing developments currently accommodate almost half of Hong Kong's population, i.e., over 3 million people.) The case study indicates that the development process for this type of work does not follow a standard pattern and the BSE frequently experiences difficulty when trying to predict the consequences of irregular or non-standard design requirements when working within restricted time constraints. The paper concludes by presenting a hypermedia framework (or model) that attempts to represent these complex collaborated design processes.

Keywords

Collaborative design; synchronous vs. asynchronous modelling; refurbishment project.

Introduction

The Hong Kong Housing Authority (HKHA) manages a large number of shopping centres. These are scheduled for refurbishment on a regular basis, i.e., on a five-year cycle, in order to maintain their commercial viability. The refurbishment project is undertaken by a project team comprising of a maintenance surveyor, a structural engineer and a building services engineer (BSE). The client (HKHA) is represented by a housing manager. During the early design stage of the refurbishment exercise the project team's main objective is to produce a schematic design that meets (or improves upon) the client's brief.

The BSE's initial task is to justify to the client's representative the scope and extent of the improvement work to be carried out. This is typically dependent upon the condition of the existing equipment. If the condition survey indicates that a major refit is necessary then this normally implies that a significant design project is required. However, when this occurs it is not unusual for the final design to deviate substantially from the early conceptual design. This occurs because of a number of factors. For example, other members of the project team may surmise that the work of the BSE is exclusively related to building systems. The common perception being one whereby the work of the BSE is the least difficult to adapt.

As a result, the BSE is frequently required to change his design(s) many times in order to cope with new constraints that may arise from changes dictated by the architect or the structural designer. Anecdotal evidence indicates that these changes typically take place with a minimum of advance warning. In other words, in the context of a shopping centre refurbishment project, the BSE has to be flexible and adaptable to facilitate frequent design changes that may occur in an unpredictable manner.

It is therefore argued that the BSE may be able to carry out his design task more efficiently if he is empowered with a more effective communication's tool for managing his design information. The tool should be able to operate in the collaborative working environment typically found in a multi-disciplinary setting. Hypermedia is considered to be such a tool. In order to verify this assumption, a collaborative design exercise will be reviewed to establish the strategic relations between the source(s) of design information and the inter-relationship between this information and the different parties involved in the project team. However, there is no intention to re-engineer or change the current the design process. At the moment the intent is to establish a model that may assist and improve upon current practice.

The Design Process

The design procedures described in this paper deal with a shopping centre refurbishment project. The procedures range from the feasibility study stage through to tendering (bidding) the project. In general the whole process consist of four major processes:

⇒ feasibility study and conceptual design;

⇒ formulation of client's brief;

⇒ detailed design; and

⇒ tender documentation.

During the feasibility study stage the housing manager (HM) provides the project team with the background information of the shopping center. As far as the BSE is concerned the information supplied by the HM should indicate (i) the location of all spaces within the complex suffering from poor or inadequate lighting levels, e.g., "dark areas"; (ii) likewise spaces suffering from insufficient ventilation; (iii) a traffic indicating the potential for increased pedestrian flow, etc. From this early information the BSE is expected to advise the client on possible modifications to the proposed design. This early work should provide the client's representative with a range of solutions that overcome the shortcomings of the existing facilities. These solutions typically include upgrading the electrical supply system; improving the lighting arrangements; the addition of a central air-conditioning system and mechanical ventilation system; adding extra lifts (elevators) and escalators; upgrading the fire service installations, etc. (In the last instance this is very important in Hong Kong where fire codes and regulations have been increased many times during the last ten years to reflect the growing concern of Government.) In addition, architectural improvements to the retail space, e.g., re-zoning, new circulation patterns and system improvements, etc., also need to be considered. And finally, suggestions from the maintenance surveyor and the structural engineer also need to be considered.

Following on from the feasibility study the conceptual design is transformed into a more generalized set of blueprints and specifications. These documents may be considered to be an extension of the original client's brief and as such constitute the general policy guidelines for the shopping center improvement. Later, the conceptual design is further developed and generally provide all of the necessary information required by a contractor to complete the tender documentation. Additional information may also be included, e.g., 3D-drawings, the client's cost estimates and anticipated construction schedule or milestones, etc.

The design procedures previously described follow a four-stage process, figure 1. The figure implies a lineal progression. However, this pattern of design development is unlikely to occur. Refurbishment projects are complicated by the number of overlapping design activities, and the frequent need to consult with other members of the design team. Hence, after launching the project at the conceptual design stage the design (product) is likely to develop in a series of sub-processes or loops whereby design ideas (and information) iterate between team members until a final decision is made. During this iterative design phase it is not uncommon for conflicts to occur between project team members simply because essential knowledge previously determined cannot be traced or has been unwittingly ignored. Therefore, although figure 1 represent the notional flow of work it lacks an underlying structure that might indicate how collaboration between project team members can be implemented.

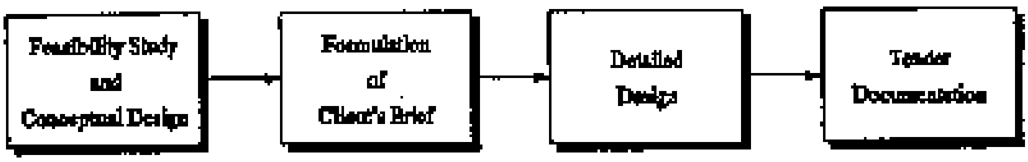

Figure 1. A four-stage process of work flow.

The Collaboration Model

In order to illustrate the process of design collaboration a simple design exercise is considered. This work involves the upgrading of the electrical supply system within a shopping centre. During the feasibility study stage the HM firstly informs the BSE of the approximate retail space to be added (or removed) from the shopping centre. As a first step the BSE assesses the existing capacity of the electrical supply system. If the existing transformer is unable to handle the addition load then a new transformer will be essential. However, the existing space may be insufficient to cope with any additional equipment. Whenever this occurs the BSE must put forward to the client possible location(s) for the new transformer room. The HM and the client's Maintenance Surveyor (MS) will need to confirm that these locations are acceptable. Meanwhile, the MS may also ask the Structural Engineer (SE) to carry out a preliminary structural appraisal on the building. Whenever existing buildings are modified, and particularly where additional loading is expected, it is wise to conduct a thorough structural assessment of the building to see whether the additional loads can be carried. If the HM, MS and the SE have no objection to the BSE's proposal, then the location and rough dimensions of the new transformer room, agreed by all project team members, can be approved.

There are two different modes that the project team members may use for the exchange of design information. Firstly, they may use a memorandum to document each transaction. In this way the conclusion of the conceptual design is achieved in an incremental manner, i.e. in an 'asynchronous' manner. Alternatively, all parties may come together to attend a design meeting where any design problem may be resolved. At the meeting minutes of are taken to confirm decisions. The second approach may be termed 'synchronous' collaboration.

Figure 2 shows a model that represents the flow of design information for the transformer room at the conceptual design stage.

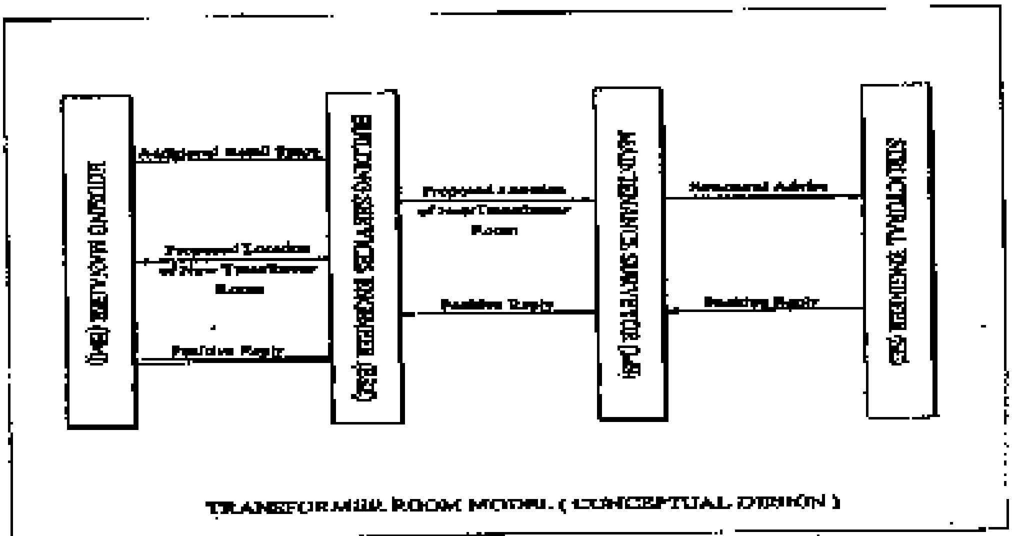

Figure 2. The model representing the flow of design information for transformer room design.

Since the dimension of time is not shown in this model, either mode of collaboration should have an identical model, i.e. synchronous or asynchronous. In practice, either collaborative mode may be adopted depending on the urgency of the design problem. Furthermore, if any of the replies from a project team member is unfavourable, the BSE may be required to repeat the process using the revised proposal. In addition to dealing with the size and location of the transformer the BSE will need to ascertain whether the air-conditioning system, fire services installation and other m&e services require upgrading or modifying. Each key element in the design process may correspond to its respective model or process, Figure 3.

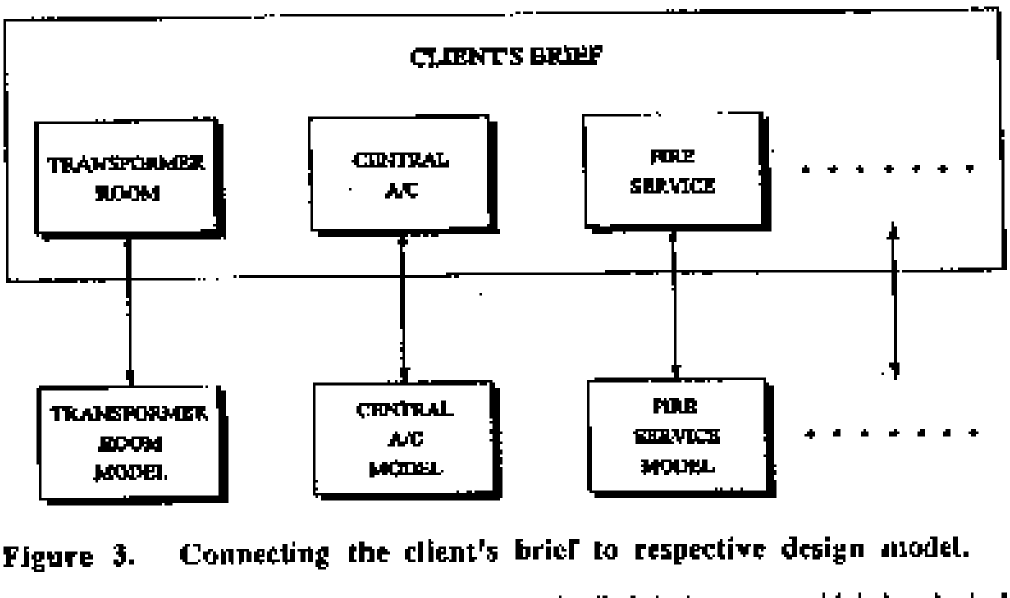

Figure 3. Connecting the client's brief to respective design model.

A similar model may also be suggested at the detailed design stage which is a logical step subsequent to the results of the conceptual design. This model also has to be connected to the one developed at conceptual design stage in order to cope with any unforeseen circumstances. If at this stage there is any new requirement that conflicts with the conceptual design, the BSE must alert the other project team members. They will collectively need to consider that all previous decisions have been endorsed and approved at the conclusion of conceptual design phase. Everyone has to acknowledge that they are aware of any possible conflicts and that they confirm that the request for change is genuine and has been approved. The BSE may sometimes find that she is unable to 'defend' their design changes simply because she cannot produce the 'evidence' of the previous agreement.

Common Factors of Collaboration

Notwithstanding the need for collaboration difficulties or obstacles frequently occur when design integration is pursued.

"Integration emerges from a strong idea. ...... The initial concept has to be strong enough to survive the design process. Once this is set, it becomes difficult to unpick or revisit during the design process without [the need] *completely to redefine it."* [Berry 1995].

Clearly a strong vision shared by all project team members will enhance the efficiency of the design process by minimizing any abortive work that may arise for revisiting earlier design. While strong ideas may not be easily defined, integration or collaborative ideas fall into two distinct categories, i.e. active and passive. Active thinking adopts the path of system or distribution-oriented design, while the passive approach concentrates more on the building fabric.

When the consensus between team members has been reached in respect of the active or passive approach, the next question is the availability of a common tool for conveying ideas. To this end, an appropriate medium for representing the content and the process of collaboration is needed. Streitz suggested an object-oriented approach where hypermedia objects serve as the 'subject matters' as well as a 'medium' for collaboration by using specific object types and exploiting their properties [Streitz 1994]. It has been demonstrated that hypermedia is appropriate for the development of a design tool for rule-based building services engineering at the preliminary design stage [Gilleard & Lee 1996]. When a BSE collaborates with team members from other construction disciplines during the early design stage hypermedia may be considered to be a suitable tool to model the flow of information. For example, it may be argued that collaborative design activities undertaken by the project team are essentially ruled-based in nature, i.e. the rules are the client's brief. As such, most of the concepts developed for the application of hypermedia in BSE design may also be extended to the development of a design tool for such a collaborative setting. However, clearly there are differences that have to be addressed in adopting the BSE concepts to a multi-disciplinary environment; a typical example is the requirement to satisfy the authoring by multi-users instead of a single user. (The application of hypermedia in a network environment is an effective configuration to meet the multi-user requirements.) Nevertheless, the strength and flexibility of hypermedia justifies the choice for such an approach. However, unstructured, the modularity of hypermedia may cause the design information to proliferate in a non-systematic manner.

Hypermedia Model for Collaboration

While Strietz suggested that an object-oriented approach is appropriate for the representation of the content and process of collaboration, the question that how to define an object for the design process of the shopping center refurbishment project has to be answered. In our case the design process can be broadly classified into two major categories: (i) design information, and (ii) the owner of the design information. (In the latter case this will generally belong to the project team members, either individually or collectively.) However, a piece of design information without an owner lacks credibility. As an illustration we will examine the transformer room question again. The statement "*the location of the transformer room is unacceptable*" would cause confusion to the design process since it is not certain whether the objection is due to structural constraints imposed by the SE or aesthetic consideration raised by the architect. It may also emanate from the MS who may be concerned about future replacement work, or possible noise pollution. On the other hand, if a piece of design information is 'owned' by one party it indicates responsibility; if it is owned by all the project team members, it implies an agreement. Hence the goal of the refurbishment project is to ensure that all design decisions are ultimately "owned" by the project team.

This relationship of "owning" can be achieved by providing a hypermedia link between the owner or project team member (created as a hypermedia object) and the corresponding design information. As the number of hypermedia links connected to the BSE multiplies, then it may be inferred that a corresponding increase in the knowledge base for the project will also increase. If we parallel these developments the HM, the MS and the SE the collective knowledge base (and the corresponding ownership links) should provide a useful design decision tool. At this moment a full hypermedia model has yet to be built. Hence it is somewhat premature to determine the degree of automation and intelligence of the hypermedia object model may possess. However, it is commonly accepted that automation of decision making process to the exclusion of human agent is counterproductive [Pohl 1996]. Therefore, the hypermedia model will be constructed in such a way that the users is able to interact with the design information and in control of the process as well.

Besides the establishment of the necessary hypermedia links between various hypermedia objects, the ability to record the decision of an user is also important. The hypermedia model should be able to track the history of the previous decision during the development of the design in order that the user may arrive at a new decision more promptly by the elimination of any out-dated alternatives.

Conclusion

A hypermedia collaborative model has been suggested to handle the design for the refurbishment of a shopping center on the understanding that each project team member has his or her discipline specific jurisdiction on the issues. However, at the moment the role of a single project leader is not apparent. Therefore, under such circumstances the quest for a common understanding of the project may well facilitate the acceptance of a hypermedia model for the exchange of design information. This will be of paramount and critical importance for the success of the proposal. The authors have good experience of using hypermedia as a design tool for a specific task (Gillcard & Lee, 1993). Whether the approach can be extended to a more generalized model is as yet an unanswered question. At the symposium an early model of the work will be demonstrated which may go some way towards providing us with an answer.

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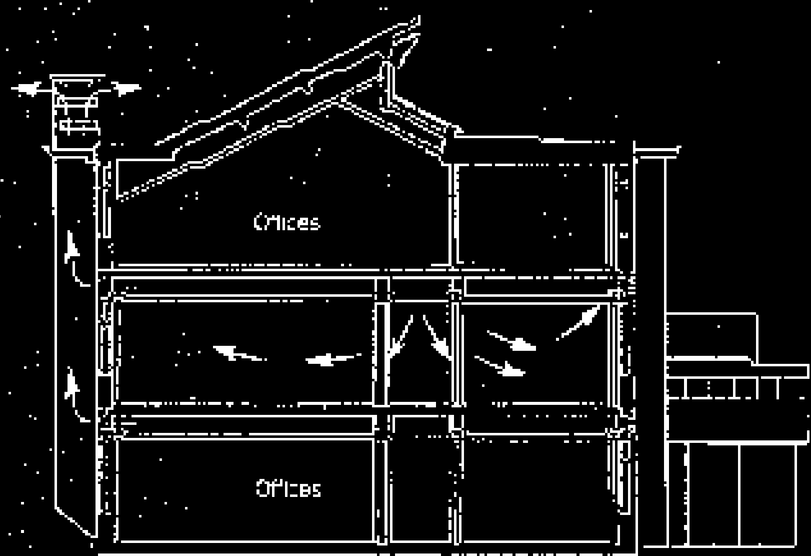

Product and Process Modelling in the Building Industry

R. Amor, editor
BRE

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Product and Process Modelling in the Building Industry

Edited by
Dr. Robert Amor
Building Research Establishment Ltd

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Product and Process Modelling in the Building Industry, Amor (ed.) © 1998 Building Research Establishment Ltd, Watford UK

Hypermedia and Collaborative Design

Dr. John D. Gilleard and LEE Yan-chyen
Hong Kong Polytechnic University

ABSTRACT: The Hong Kong Housing Authority (HKHA) manages a large number of shopping centers. These are scheduled for refurbishment on a regular basis, i.e. on a cycle of approximately five to seven years, in order to maintain their commercial viability. The refurbishment project is carried out by a project team of building professionals. During the early design stage of the refurbishment exercise the project team's main objective is to produce a schematic design that meets (or improves upon) the client's. The building services engineers (BSEs) employed by the HKHA are responsible for the design, installation, operation and maintenance of all mechanical and electrical (m & e) systems associated with HKHA developments. As regards the refurbishment of the existing shopping centers, the BSE's initial task is to justify to the client's representative the scope and extent of the improvement work to be carried out. The BSE is frequently required to change his design(s) many times in order to cope with new constraints. Anecdotal evidence indicates that these changes typically take place with a minimum of advance warning. In other words, in the context of a shopping center refurbishment project, the BSE has to be flexible and adaptable to facilitate frequent design changes that may occur in an unpredictable manner.

In this paper, it is suggested that hypermedia is an alternative paradigm to model the work of the HKHA BSE in respect of the shopping center refurbishment project in consideration of the complex nature of the design task. By adopting a collaborative design approach, the paper presents the results of the analysis of the design process adopted by the HKHA project team with reference to such factors as synchronous vs. asynchronous. Concepts in complex problem solving are also explored especially on the agent-based decision support systems. The justification of developing a tool to cope with changing conditions of a complex design problem instead of providing a solution for a pre-determined problem is argued. This paper shows the implication on the architecture of the hypermedia model for building services systems design process under the collaborative environment.

KEYWORDS: Collaborative Design Process; Hypermedia; Refurbishment Work.

1. INTRODUCTION

Building services engineering (BSE) design is thought to be a 'semi-structured' process. It has been suggested that design computing should be carried out in such a manner that the designer may retain control over design and calculation procedures rather than relying on 'black box' type software (Zachariah & Eames 1996). The 'parametric' nature of BSE makes it imperative that BSE design software should provide facilities for relatively quick 'what if' type of analysis. On the understanding of such being the nature of the design process, it has been shown that a design tool for rule-based BSE design is appropriate using hypermedia as the authoring mechanism. The argument was supported by the construction of a HyperCard model for 'fire sprinkler layout design' based on a set of safety rules and codes (Gilleard & Lee 1994).

Evidently, hypermedia is a favourable environment to facilitate the development of design software for a design process which may be more 'controllable' by the user. The 'if then' relation (as demonstrated in the sprinkler layout deign model) allows the designer to critically examine and question strategic relationships between data/information embedded within the specialist knowledge base. However, direct conversion of the Rules into a hypermedia document does not provide adequate clues in order to ensure that the user retrieves the correct design information. Re-arrangement of the design requirements in a non-lineal manner helps BSE designer more easily interrogate the formal rules and to more effectively explore strategic design information embedded with the document, which has been realized within the hypermedia environment.

In the case of the refurbishment of a shopping center in HKHA, the BSE designer has found that the design task is much less 'controllable' in the sense that the emerging design information are very often beyond his expectation. It may be the result of the interaction between the various members of the project team as well as the complex nature of a refurbishment project. Within the HKHA a team of building professionals normally develops the client's scope of work, or brief. These include the maintenance surveyor (MS), the building services engineer (BSE), and the structural engineer (SE). The housing manager (HM) usually acts as the client's representative. The development of the client's brief starts with a preliminary condition survey of the shopping center. As a result a list of repair / replacement items will be determined. This list is used to prepare the initial refurbishment work conceptual design. Later, as additional information is determined, e.g., detailed fabric and system survey, update of tenant's list etc, the scheme design is developed. During this stage the collaboration of all team members is essential. At the HKHA this is based on established channels through which, the exchange of design information is formalized. Nevertheless, the flow of design information is by no means well structured. Each project team member may come up with a different (or slightly different) design option any time during the design process, which may be rightly justified in accordance with the latest survey results. The lack of a flexible system that could effectively reflect such changes may result in problems when tracking a particular design decision at a later stage. As such, the concept of developing a BSE design software may be extended from retaining more control over the design to the providing of higher flexibility in coping with unpredictable changes.

2. CHARACTERISTICS OF REFURBISHMENT PROJECT

Refurbishment work differs from new construction project in that the scope of work is seldom clearly defined at the outset of the design stage. The common factors that will influence the refurbishment project are twofold, i.e. technical factors and non-technical factors. The former include the condition of the existing building facilities and engineering design standards. The latter comprise factors in commercial, financial, social and political aspects. [The building professionals that make up the HKHA project team normally limit their role to technical and engineering aspects of the refurbishment project.]

A typical refurbishment project may be defined in two major areas, i.e., maintenance of the existing building facilities and the addition of new facilities. In both cases the HKHA aims to enhance the commercial value of the shopping center. Maintenance work normally includes the replacement of tiles and finishes, improvements to false ceilings and light fixtures, as well as upgrading the electrical wiring systems, etc. This work is normally planned in such a way that new materials, components and systems are used. In this way the HKHA is able to improve the aesthetics of the centers as well as the efficiencies of the facilities under maintenance. On the other hand, new facilities may comprise additional retail space and the construction of new central air-conditioning plant. When this occurs it is not uncommon for a new building block to be constructed as an annex to the existing shopping center. The extra space provided allows for an increase in the potential rental income. Under such circumstances the refurbishment project needs to be justified in terms of commercial viability. In such situations the refurbishment project cost may be greater than HK$10m (~US$1,290,000).

3. DECISION MAKING AS A COMPLEX PROBLEM

Observational evidence indicates that HKHA refurbishment projects may be characterized as complex design problems given the frequency of unpredictable design changes. This added uncertainty mitigates against pre-determined design solution. The HKHA was the first Government Department in Hong Kong to acquire ISO 9000 certification in respect of its quality assurance systems in the construction and maintenance of public housing. In this respect, procedures for all major works relating to the design, construction, operation and maintenance of housing are stipulated in the form of quality manuals. These manuals clearly identify procedures regarding the responsible persons, the purpose of an action, the approving authority, etc. Hence, these quality manuals attempt to ensure a consistent performance of individual officers irrespective of their experience and background. Using the information embedded within the manual a flow chart indicating the design processes associated with a refurbishment project may be produced, Figure 1. However, one obvious shortcoming of the flow chart is the lack of design intent representation. Nor is it easy to determine how the design concepts were developed. For example, although the feasibility study may examine an increase (or decrease) of retail space from the perspective of system design – say HVAC – other factors such as the capital investment pay-back period, the social impact of the work or political considerations may be ignored.

On the other hand, the HKHA does have a well-established documentation system. For example, it has been estimated that over 90% of the information flow between various project team members is conveyed in a written form, e.g., e-mail, memoranda, discussion papers, minutes of meetings, etc. Thus consensus within the project team is typically reached in an asynchronous manner, i.e., each project team member has to make his or her design choice based on information previously input by other team members. Much of this information is relatively standard and non-controversial. Consequently explanations and comment is not required. Unfortunately, significant design changes may take place without documented reference to other team members. The result of this passing backward and forward of non-documented design changes leads to confusion and the use of inappropriate design details. Therefore it is logical to argue that any system or tool capable of providing the required information at the right time should enhance the productivity of the project team by minimizing abortive work and backtracking.

Within the HKHA analysis of the design information flow pattern clearly suggests that there is no effective link between the CAD drawings and the documentation that represents the design intent. The process also lacks a sound referencing system of the chronology of design changes. Pohl in his work on the need for collaborative design representation also emphasizes this issue (Pohl 1997). CAD drawings usually denote the geometric changes in the revision notes but reasons and rationale behind these changes are recorded elsewhere in the form of memoranda and/or variation orders that have been issued to formalize the changes. The fragmented nature of the flow of design information creates many difficulties in the tracking archived information. For example, where conflicting design data is found it is often difficult to verify the source of the inconsistency. Each member of the project team plays the role of controller and monitor, Figure 2, although veracity and concurrence [of other team member's design changes] is frequently lacking. Clearly the complex nature of the information flow between the controllers who collaborate in a refurbishment project has to be further examined.

4. COLLABORATIVE DESIGN

It has been suggested that the integration of Information Technology (IT) and the design and construction process hinges on organization's level of maturity, [Hinks et al, 1997]. Clearly there are differences in opinions that how IT should integrate with a design process. Regarding the shopping center refurbishment project, it may be possible in principle to write a computer programme to simulate the role of the BSE or MS if engineering design is the only criteria when developing the client's brief. In other words, it is perceived that this part of the design process may be automated. However, refurbishment design work is more than the application of simple design algorithms or heuristics. Reality imposes on the design problem a complexity that is frequently unpredictable and chaotic. A simple example illustrates this point. The proposal was to construct a new transformer house. This was necessary to provide additional electricity for the new air-conditioning plant to be installed in one of HKHA's existing shopping centers. The design evolved based on this assumption. However, at a very late stage of the design process the drainage department indicated that the proposed location of the new transformer house had already been allocated as a drainage reserve. Consequently, one set of designs had to be abandoned and a second developed. By this time the project deadline was looming ever closer and a new location for the transformer house location, cable routing and switch room had to be found quickly. These late design decisions naturally effect design costs, as well as tending to increase total capital expenditure.

The preliminary analysis of the collaborative design process of a refurbishment project suggests that the requirements of a computer-aided design tool for such an application should be, at least twofold, i.e. flexibility to cope with the unforeseen changes and the ability to associate relations between changes in order to facilitate subsequent tracking.

5. FLEXIBILITY FOR PARTNERSHIP AND COLLABORATION

It has been suggested that flexibility in the user-interface should be provided in order to facilitate the human-computer partnership for tackling complex problems, and the flexibility may be achieved by building computer-based agents in the process model such that solutions may be evolved interactively (Pohl 1997). Agents essentially mean components of decision making models (that may involve a group of humans such as a committee, board, or design team), that are translated into a computer-based environment where the agents may reason or interact with each other or accessing a knowledge-base.

The rationale behind the concept of agents is that a decision-support system should be designed as a set of tools rather than as solutions to a predetermined set of problems. However, the development of a computer-based decision-support system requires the construction of autonomous components (i.e. agents) that may incorporate different kinds of knowledge and capabilities in order to co-operate with other components concurrently, and independently (to a certain extent). Clearly, validation of the accuracy of the options proposed by the agents is crucial in order to ensure the reliability of the results in relation to the knowledge-base that the agents are interrogating. The effort in carrying out such validation process may be so significant that the cost-effectiveness of such a computer-based system could be questionable.

As an alternative, the handling of information in a relatively fluid manner in hypermedia environment has been demonstrated in the construction of the sprinkler layout model previously, evidently with much less effort for prototyping of the model. In fact, hypermedia has been considered as an appropriate medium for representing the content and the process of collaboration (Streitz 1994).

6. DESIGN INFORMATION FLOW AND HYPERMEDIA

Hypermedia represents a class of authoring tools that organize information in a non-linear manner with multimedia capability, which resembles the pattern of information flow between users in a broad sense. On the other hand, recent research trend suggests that networked computer systems such as the World Wide Web (WWW) has inherent advantages as a medium/tool for collaboration and communication in a design process (Fowler 1997). [HyperCard, one of the most popular hypermedia systems developed by Apple, has the navigating and searching features that have greatly influenced the evolution of the WWW.] As such, hypermedia coupled with a networked system may be the appropriate paradigm for modelling the collaborative design process for the refurbishment of shopping centers.

Figure 2 indicates the incoming information from the MS or SE to the BSE. This information flow is incremental in nature, i.e. the notice indicating a change represents a portion of the design scheme which is being affected. The BSE has to integrate the latest change with the original design and produce a revised drawing or modified client's brief for the entire design scheme. If the design scheme is not updated immediately, it may cause confusion when later identifying design revisions. Updates not registered may also lead to confusion where two different design concepts may conflict with each other, Figure 3. First, each team member will maintain his own data model and pass the data comprising the change information to other member who would then update his own data model accordingly. It has the merit of higher transmission speed and less time in preparing the documentation by the sender. However, the receiver has to maintain a systematic and clear record of the changes in order to avoid the confusion as mentioned previously and to facilitate subsequent tracking. The second alternative concept of configuration is to pass the complete revised data model to other members who would overwrite his own model if both models are of the same file type. Clearly it will minimize any inconsistency arising from poor management of change data and the receiver may see the implication of the change more clearly with respect to the entire design scheme. Nevertheless, it will be subject to a hardware constraint in that the limited bandwidth of the network system may slow down the transmission speed of the complete data model.

The data model is essentially a hypermedia model that may contain change data in the form of text, 3D graphics (or virtual reality), hypermedia links to other data files such as CAD drawings. Under such an arrangement, a user is free to navigate in his data model for updating change information, tracking archive design and preparing new information for distribution to other user. Notwithstanding the fluid manner in accessing design information, the project team is still collaborating in an asynchronous mode. It may be possible to configure the communication in such a way that team members could collaborate in a synchronous mode by holding a virtual design conference on-line in order to achieve a real time interaction between team members. While the actual set up for such a synchronous collaboration has yet to be realized, the real need for this mode of communication is questionable. A team member may have to sacrifice his flexibility in managing his time in order to attend a virtual conference. Experience shows that unless a major issue is to be considered, the arrangement to ask all team members to attend a virtual conference could be very tedious and therefore may not be of any practical value. The crucial requirement is that the computer system should allow a project team member to capture all the design changes, which could be traced readily and should provide the flexibility to accommodate abrupt changes without the need of rebuilding the entire data model again.

It has been demonstrated that hypermedia is appropriate for the development of a design tool for the rule-based building services engineering at the preliminary design stage (Gilleard & Lee 1996). Hypermedia models in respect of the collaborative design process for the refurbishment project are being developed on the basis that those concepts developed previously for preliminary building services engineering design may be extended and applied to cope with the collaborative environment.

7. ELEMENTS OF THE COLLABORATION MODEL

It has been shown that by identifying the different types of relations between the various information objects, the effectiveness of retrieving and updating of the hypermedia model can be greatly enhanced (Gilleard & Lee 1996). Therefore, the pre-requisite condition with regard to the construction of a hypermedia model for the collaboration design process is the identification and the subsequent classification of the types of information being handled.

In hypermedia, information may be represented and carried in the form of nodes as well as links between nodes. Nodes and links may be seen as objects that could be created, copied, moved, modified and destroyed. In the case of a refurbishment design project, the collaboration model basically consists of two main types of information, i.e. the design information/data and the owners of these information. These may be further broken down into different major elements. The design information/data mainly consists of the improvement proposal, standard information (e.g. engineering standard or practice codes) and specific design requirements (e.g. size and location of a chiller plant). Owners of such information refer to the members of the project team including housing managers, maintenance surveyor, structural engineer and building services engineer. Clearly there are relations between the elements of the two different types of information as well as those between the elements belonging to the same information types. There is no active relation between the elements of the design information/data (though the specific design requirement is a function of standard information). Also, the relations between the information owners will not have any significant meaning unless they are connected to the design information/data. As a result, the remaining relations that may be significant for consideration are the actions that the owners will take with regard to the design information/data. The owner may propose, review or identify a set of design information/data, Figure 4. It can be seen that the agreement between the various owners may be reflected by checking the "PROPOSE" relation through which all owners point to the same version of "Improvement Proposal" or in hypermedia term the same information object.

Once again the strength of adopting the classification of relations between information objects for facilitating the information flow and subsequent retrieval of design decision has been illustrated. Ongoing work is being carried out to identify strategic relations of the collaborative design process. The configuration arising from these relations are being constructed and tested against the performance standard of the existing system for handling collaborative design information.

8. CONCLUSION

The design process of the refurbishment of a shopping centre has been analysed. Request for design changes at the very late stage of the design process is not uncommon. The project team has to be flexible in coping with these changes which may not be easily predicted and are beyond their control. The collaborative design process is therefore seen as a complex problem that warrants the development of a system or design tool able to provide such flexibility not readily available in conventional approach. Hypermedia in a networked environment has been suggested as a suitable paradigm for such development work. Further research is being carried out to work on an optimum configuration with regard to the implementation of hypermedia that would parallel the collaborative design task.

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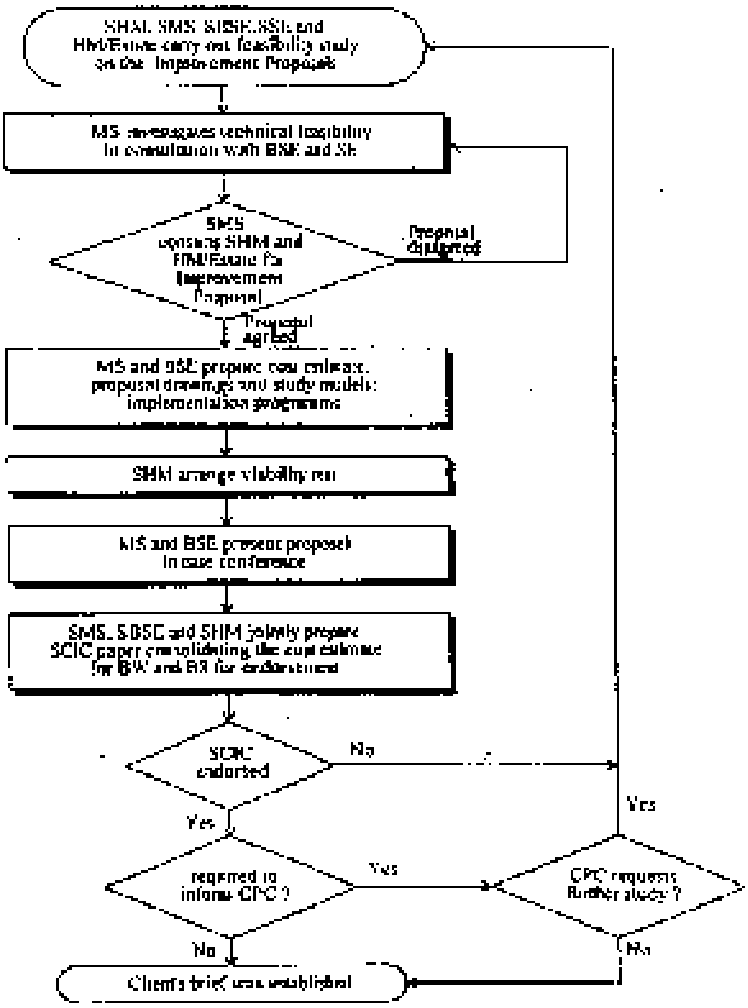
Figure 1. The Formal Work Flow.



ABBREVIATIONS:

SHM :	Senior Housing Manager	HM :	Housing Manager	SCIC :	Shopping Centre Improvement Committee
SMS :	Senior Maintenance Surveyor	MS :	Maintenance Surveyor	CPC :	Commercial Properties Committee
SBSE :	Senior Building Services Engineer	BSE :	Building Services Engineer		
SSE :	Senior Structural Engineer	SE :	Structural Engineer		

Figure 2. The Role of the BSE in controlling the flow of design information.

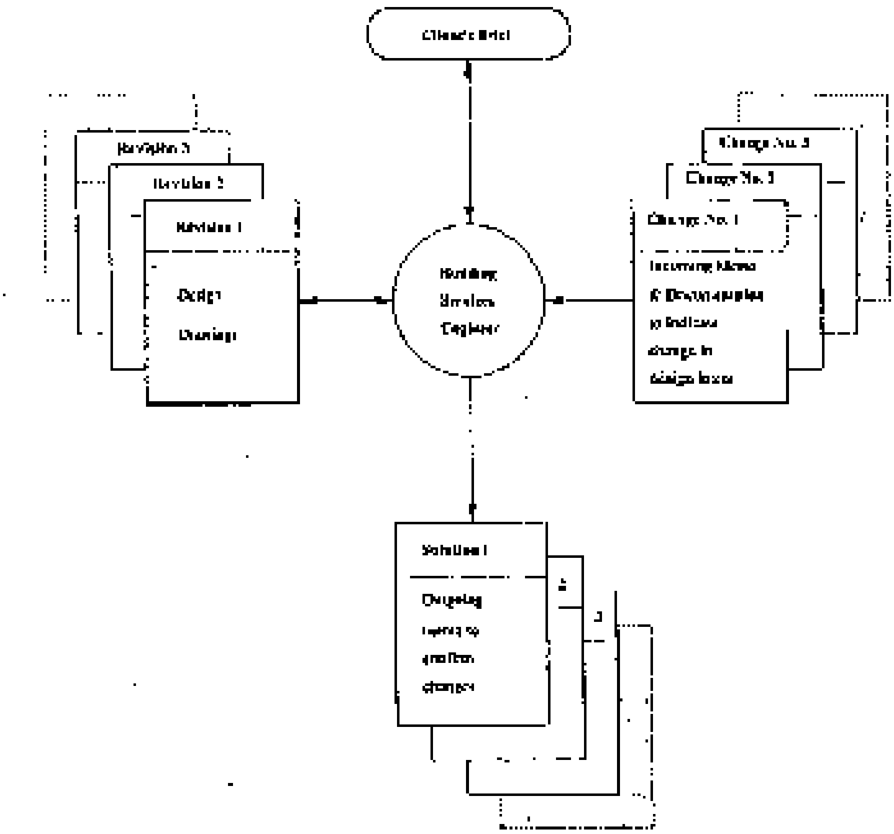


Figure 3. Two different concepts in managing design changes.

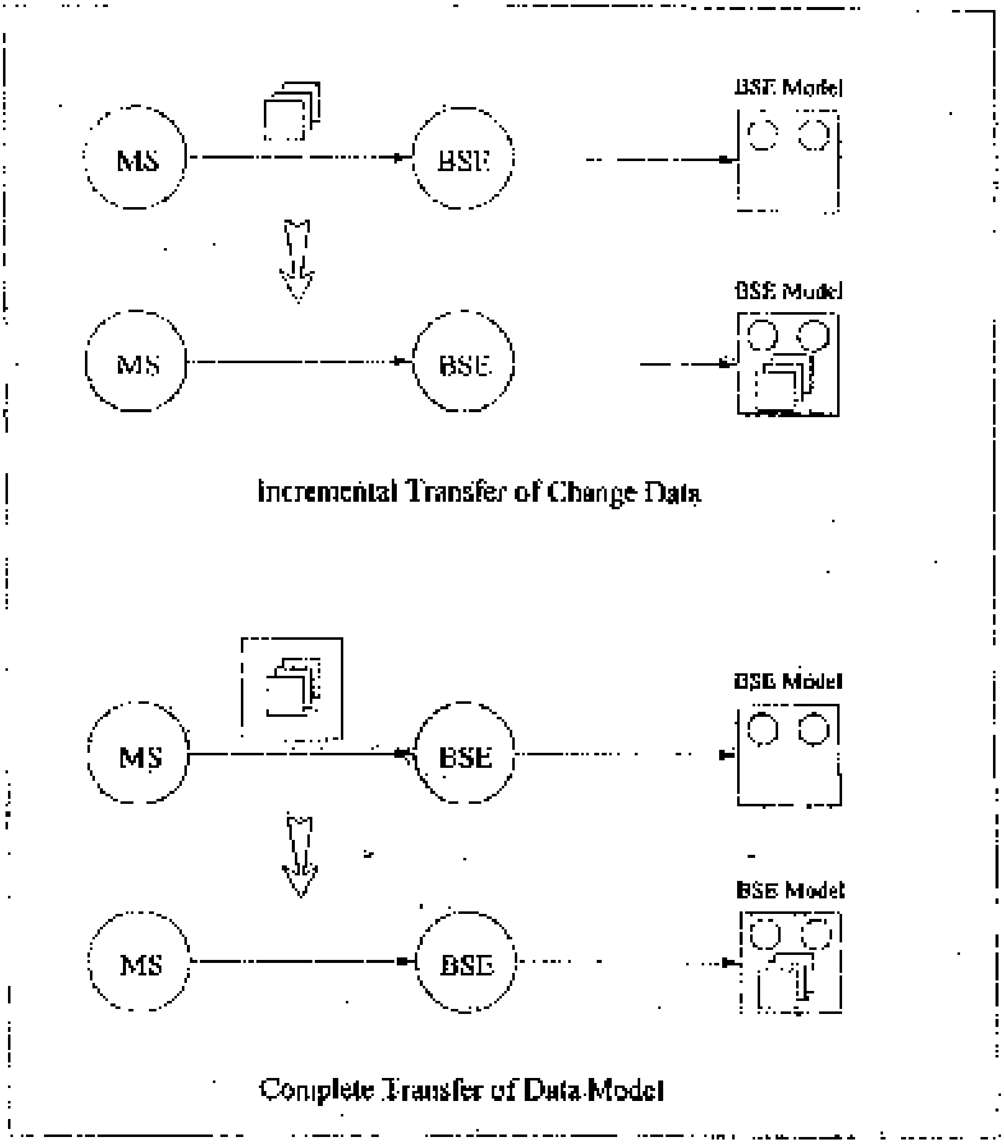
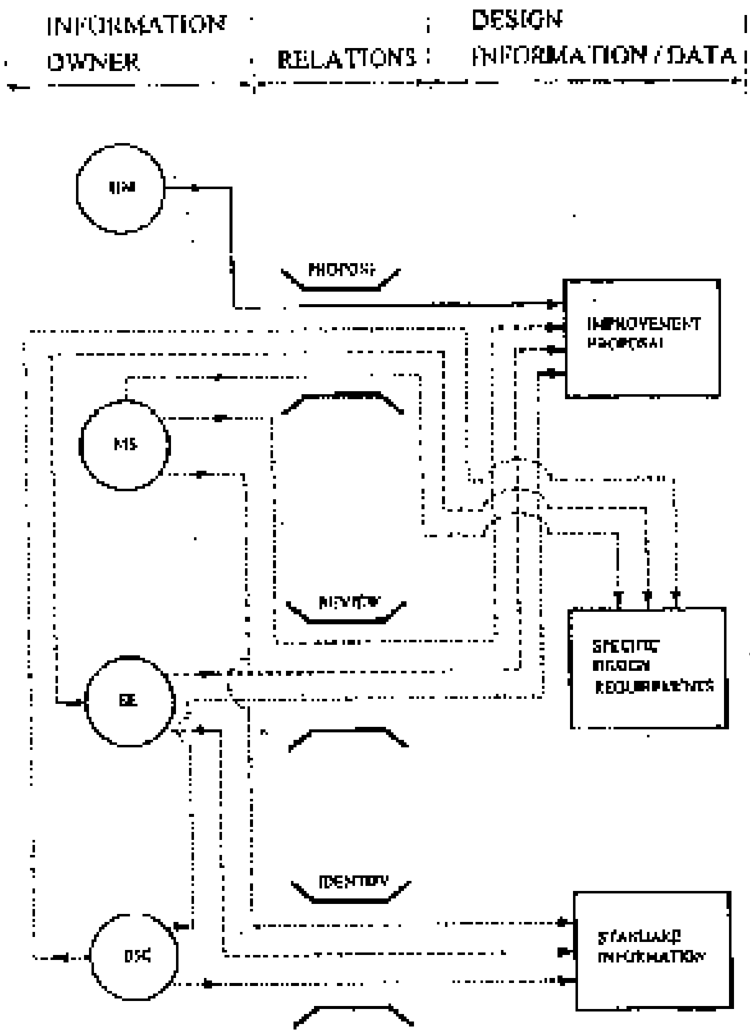


Figure 4. Typical Classification of Relations between Information Objects



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Refurbishment of building services engineering systems under a collaborative design environment

Lee Yan-chuen, M. Phil, John D. Gilleard *

Department of Building Services Engineering, Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong, China

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Refurbishment of building services engineering systems under a collaborative design environment

Lee Yan-chuen, M. Phil, John D. Gilleard *

Department of Building Services Engineering, Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong, China

Abstract

In this paper hypermedia is suggested as a suitable paradigm to represent the design processes associated with a shopping center refurbishment project. In addition, by adopting a collaborative design model, the paper makes reference to such factors as synchronous vs. asynchronous and active vs. passive modeling. Concepts in complex problem solving are also explored such as the soft system methodology as well as the application of agent-based decision support systems. Identification of primary information elements and analysis of the relations between these elements indicates that the flow of design information may be readily represented in hypermedia which features nonlinear characteristics in organizing information. The justification of developing a hypermedia tool to cope with changing conditions of a complex design problem instead of providing a solution for a predetermined problem is also argued. The paper illustrates the complex nature of collaborative design process with reference to a case study associated with the building services systems design for a Hong Kong Housing Authority refurbishment project.

Keywords: Collaborative design; Design intent representation; Complex problem solving; Hypermedia

1. Introduction

The Hong Kong Housing Authority (HKHA) manages a large number of shopping centers. In order to maintain their commercial viability the shopping centers are refurbished on a regular basis, i.e., on a cycle of approximately 5 to 7 years. A project team (PT) consisting of a maintenance surveyor (MS), a structural engineer (SE) and a building services engineer (BSE) undertake this work. In addition, the client (the HKHA) is represented by a housing manager (HM). The initial task is to prepare a client's brief for the refurbishment work. The client's brief is normally carried out by the HM. Subsequently the PT will develop outline designs that meet (or improve upon) the original brief.

The HKHA refurbishment programme is normally planned in such a way that four to five shopping centers are refurbished each year. The annual budget for this work is approximately HK\$400 million, or ~US\$50 million. Fig. 1 indicates the scope of work for a typical refurbishment project. In this example, an additional 1800 m^2 of space for food and retail premises has been proposed. This will be constructed adjacent to the existing market at an estimated cost of ~HK\$90 m. The estimated cycle time for the project is 3 years.

* Corresponding author. Fax: +852-2774-6146; e-mail: bejohn@polyu.edu.hk

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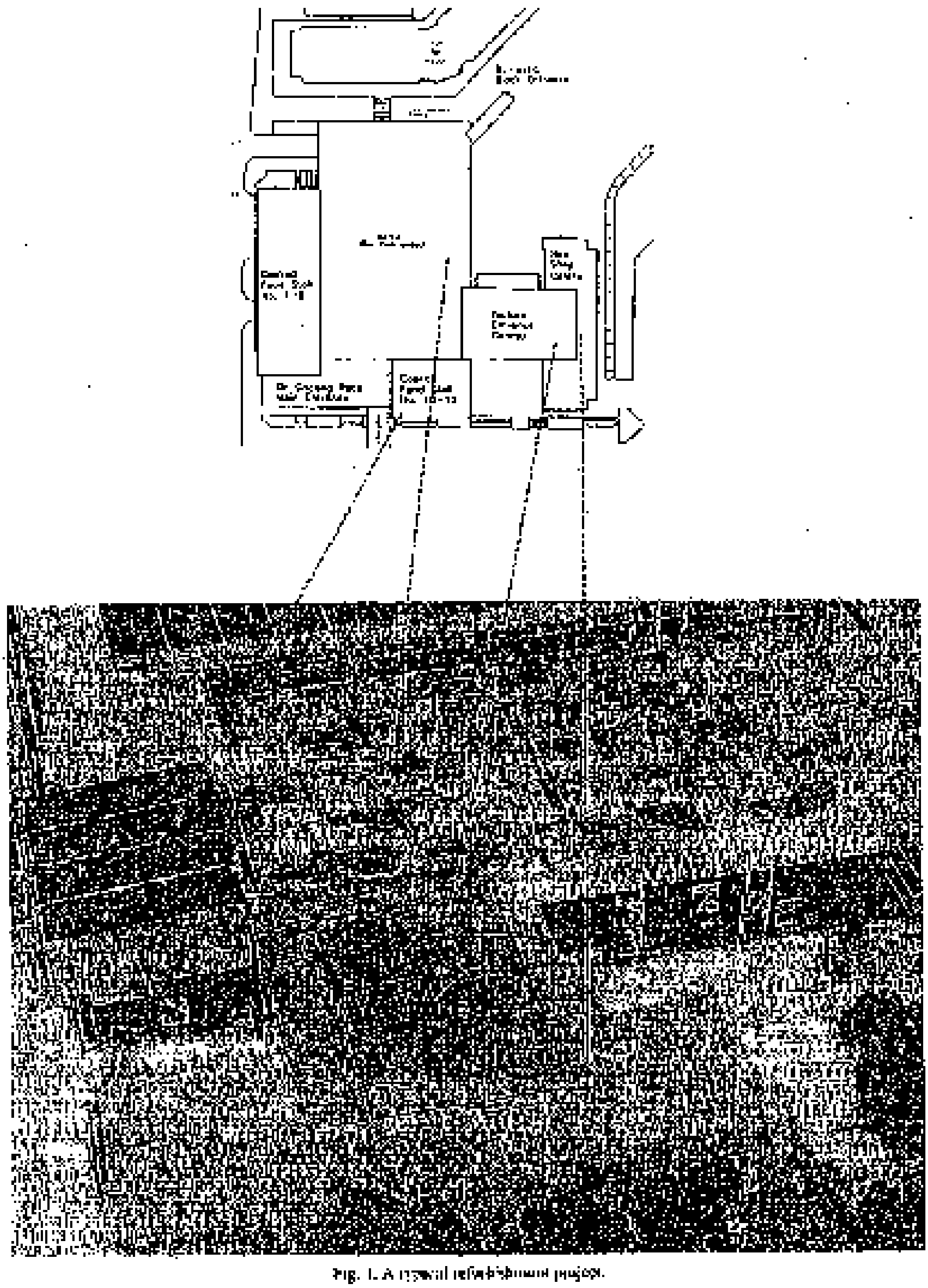


Fig. 1. A typical refurbishment project.

The BSE is responsible for the design, installation, operation and maintenance of all mechanical and electrical (m&e) systems associated with HKHA developments. Hence the BSE's initial task is to justify to the HM the scope and extent of the improvement work to be carried out. This is typically dependent upon the condition of the existing facilities. If the condition survey indicates that a major refit is necessary then this normally implies a significant project is required. However, whenever this occurs the final design typically deviates substantially from the early conceptual design. As a result, the BSE is frequently required to change his design(s) many times in order to cope with new constraints that may arise from changes dictated by the MS or SE (who normally assume the role of project architect). Anecdotal evidence indicates that these changes typically take place with a minimum of advance warning. In other words, in the context of a shopping center refurbishment project, the BSE has to be flexible and adaptable to facilitate frequent design changes that may occur in an unpredictable manner.

It has been shown that the design procedures for the refurbishment of a shopping center may be broken down into four major processes [1]:

feasibility study and conceptual design
formulation of client's brief
detailed design
tender [bid] documentation

Experience obtained from previous projects indicates that the development of a design scheme from the conceptual design stage to the detail design stage does not follow a regular pattern. The activities undertaken by the project team during the development of the design scheme include (i) communication between the team members regarding their respective design intent; (ii) the management of the design information; and (iii) debate (and confirmation) of the issues defining the extent of the refurbishment work. However, whereas standard business model procedures prescribe formal channels for seeking authorization of the design proposal these procedures are usually inadequate to represent the design changes themselves. In addition, decision making within the PT is frequently ambiguous. Hence, given the complexity of the real world when arriving at a design option, the application of these standard business procedures are very limited.

2. The design process

The nature of a design process may be seen as a complex decision-making problem. However, as Pohl suggests "the complexity of design does not appear to be due to a high level of difficulty in any one area but the multiple relationships that exist among the many issues that impact the desired outcome" [2]. Pohl continues by arguing that flexibility is required when constructing the design user-interface between man and computer, "human–computer partnership can evolve in directions and capabilities that cannot be predetermined at the outset" [3]. Pohl's work uses multiagents or computer-based agents that help designers to interrogate existing knowledge bases. These multiagents also facilitate the communication between the designers (or the human agents) as well as between the various computer based agents. This is deemed necessary with information intensive activities. By providing the required level of flexibility for decision-making it should be possible to develop a versatile design tool rather than simply adopting a 'canned' design solution.

Applying these procedures to the refurbishment of a shopping center, it should be possible to derive the pattern (or information network) from previous projects. The initial aim would be to determine whether a 'standard' design template is feasible and if this standard could be used when planning future projects. However, experience indicates that such a template would be too simplistic and unlikely to be able to cope with normal design variations or the interpretation of this information by the various members of the PT whose professional experience is typically at variance with one another. Following the same argument, a localized problem within a refurbishment project may not be readily reflected in the standard template. It is normal that at the early stage of a design process the amount of useful information (as well as the understanding of the client's requirement) is low when compared to the subsequent stages of the design process. Hence, given the limited information, the accuracy of any design proposal put forward by the project team is unlikely to be high and unlikely to meet all of the client's requirements. As such, it may be logical to develop a methodology or a system that would facilitate the evolution of a design proposal along with the increasing amount of information (or constraints). The pursuit of a information flow model that attempts to mimic the actual collaboration model could be very ineffective though it may not be entirely impossible.

The perception that real-world problems are frequently complex and less well defined is also shared by Checkland and Scholes. Checkland's soft system methodology (SSM) theory helps to organize 'messy' real world situations. SSM is realized on the basis of system thinking: "'the system' is no longer some part of the world which is to be engineered or optimized, 'the system' is the process of enquiry itself" [4]. With regard to the collaborative design of a shopping center refurbishment project, the SSM approach implies that the collaborative design process may not be the system to be defined, the methodology to model a changing design process has to be defined. SSM is highly defined and described but is flexible in use and broad in scope. It is intrinsically a collaborative approach. Checkland argues that the '*sensible man*' will involve other people in the process of problem solving.

3. Documented procedures vs. real-world situation

The HKHA was the first government department in Hong Kong to acquire ISO 9000 certification in respect of its quality assurance systems in the construction and maintenance of public housing. In this respect, procedures for all major works relating to the design, construction, operation and maintenance of housing are stipulated in the form of quality manuals. These manuals clearly identify procedures regarding the responsible persons, the purpose of an action, the approving authority, etc. Hence, these quality manuals ensure a consistent performance of individual officers irrespective of their experience and background. Using the information embedded within the manual a flow chart indicating the design processes associated with a refurbishment project may be produced, Fig. 2.

However, one obvious shortcoming of the flow chart is the lack of design intent representation. Nor is it easy to determine how the design concepts were developed. For example, although the feasibility study may examine an increase (or decrease) of retail space from the perspective of system design—say HVAC—other factors such as the capital investment pay-back period, the social impact of the work or political considerations may be ignored.

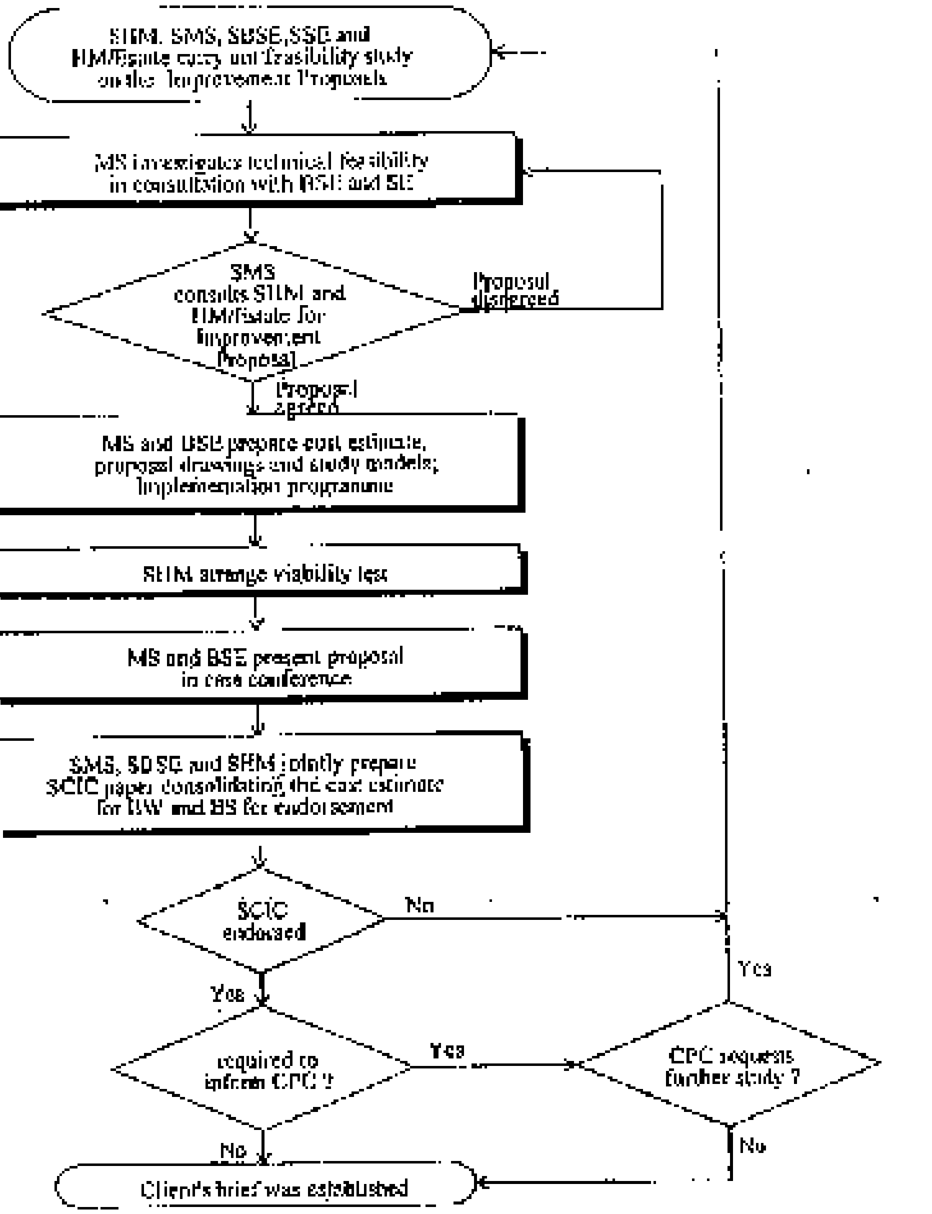
The relationship between the various responsible persons is not explicit. In addition, how they interact with each other to draw their conclusion on the feasibility of a particular improvement item is not well defined.

It may also be argued that the development of the client's brief by the EM is by no means a sequential one. For example, it is common to override earlier design decisions at a later stage of the work. These changes may be due to unforeseen circumstance occasioned by a lack of commonly agreed design rules or design data within the PT team. For example, the project shown in Fig. 1 suggests an addition of a 'feature entrance canopy' on the assumption that the shopping center patrons will access the building through this entrance. New escalators will also be added under this canopy in order to lead the patrons from the entrance to the new cooked-food stalls provided on the podium level. However, the local residents may reject the assumption that the proposed entrance will have the highest pedestrian flow when the design proposal is published for public consultation. In this case the PT has adopted a different assumption. This is likely to trigger a series of design changes including the relocation of the escalators. In addition, it is common for ambiguity in design intent to occur between team members.

However, when the collaborative design process is considered as a complex problem, it does not imply that the process is not definable. The question is whether there exist any critical characteristics in the information flow. If such characteristics do exist it should be possible to abstract and rationalize the information flow to establish a meaningful collaborative design model.

4. Elements of the perceived collaboration model

Constructing a basic information model, Fig. 3, can identify the elements that constitute the BSE design process. These elements may be classified into two distinct types by virtue of their relationship with the BSE. The first classification may be termed



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SSE	Senior Structural Engineer	SE :	Structural Engineer		

Fig. 2. The overall work flow

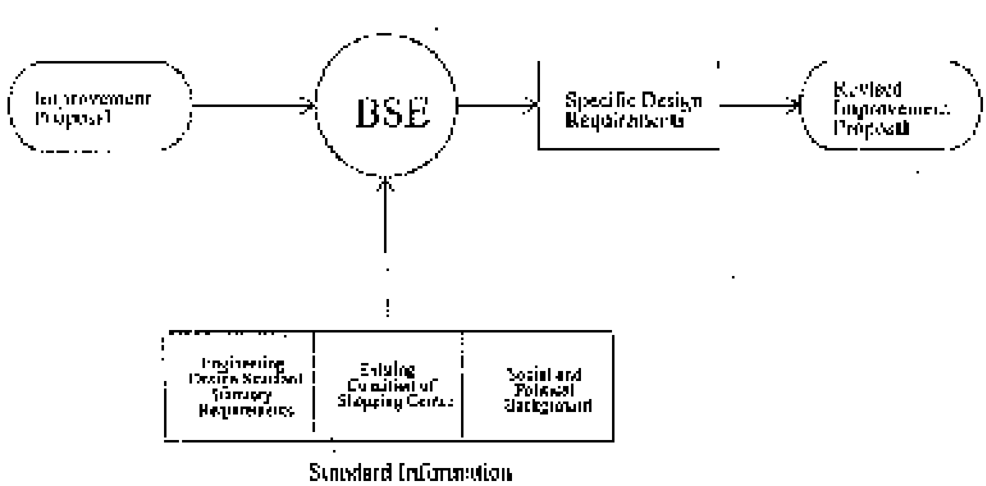

Fig. 3. The basic model.

fixed data, or standard information. Typically the BSE has no jurisdiction to change fixed data. Fixed data includes engineering design standards, codes of practice, statutory requirements, and the existing fabric condition of the shopping center. In addition, the social and political background of the shopping center development may also be classified as fixed data.

The second type of information may be classified as variable data. Variable data can usually be manipulated (changed) by the BSE. Variable data includes improvement proposals (and the subsequent revisions), specific design requirements, and the client's brief. Combining the fixed and variable data sets helps to build a structured framework that defines the refurbishment design model, i.e., to identify, elaborate, communicate and finally articulate the project's objectives. Hitchcock proposed a similar model for the life cycle costing of buildings [5]. That is, three primary informational elements are required to represent the design intent: project objectives, a product model of the design, and design context assumptions. Project objectives are the stated performance goals that a particular building design is attempting to achieve. The product model is a complete detailing of the physical components of a building and the dynamic operation of the building systems such as the air-conditioning control system. Context assumptions define the operating environment within which the building has been designed to achieve the stated project objectives, such as design cooling load to size an air-conditioning system.

The standard information required by the BSE basic model might be said to be comparable to the design context assumption proposed by Hitchcock. Similarly, the refurbishment improvement proposals play a role equivalent to that exhibited by the product model. However, specific design requirements differ from the project objective. For example, the former represents the physical parts of the model while the later addresses the conceptual issues. This may be illustrated by the following example. The client's brief typically states "to provide central air-conditioning system to all common areas of the shopping center". This statement may be categorized as an improvement proposal, forming a part of the variable data set. The location and space for the selected chiller plant also forms a part of the variable design requirements. On the other hand, the weather data, cooling load calculation formula, environmental constraints on the selection of chiller plant, etc. typically form the major part of the standard, or fixed information set. Thus the improvement proposal must be validated against both the variable and fixed design requirements. If no other unfavourable conditions are observed by the BSE, e.g., poorly coordinated services, inappropriate plant room location or sizing, then the revised refurbishment proposal will be noted and accepted. However, where conflicts do occur, redesign will be necessary. This is common with refurbishment projects. Therefore, as far as the basic model is concerned, there are three primary information elements required. These may be termed the improvement proposal (and subsequent revisions), standard information and, finally, specific design requirements.

At this stage collaboration between the BSE and other PT members has yet to be established. However, if all PT members apply the same basic model

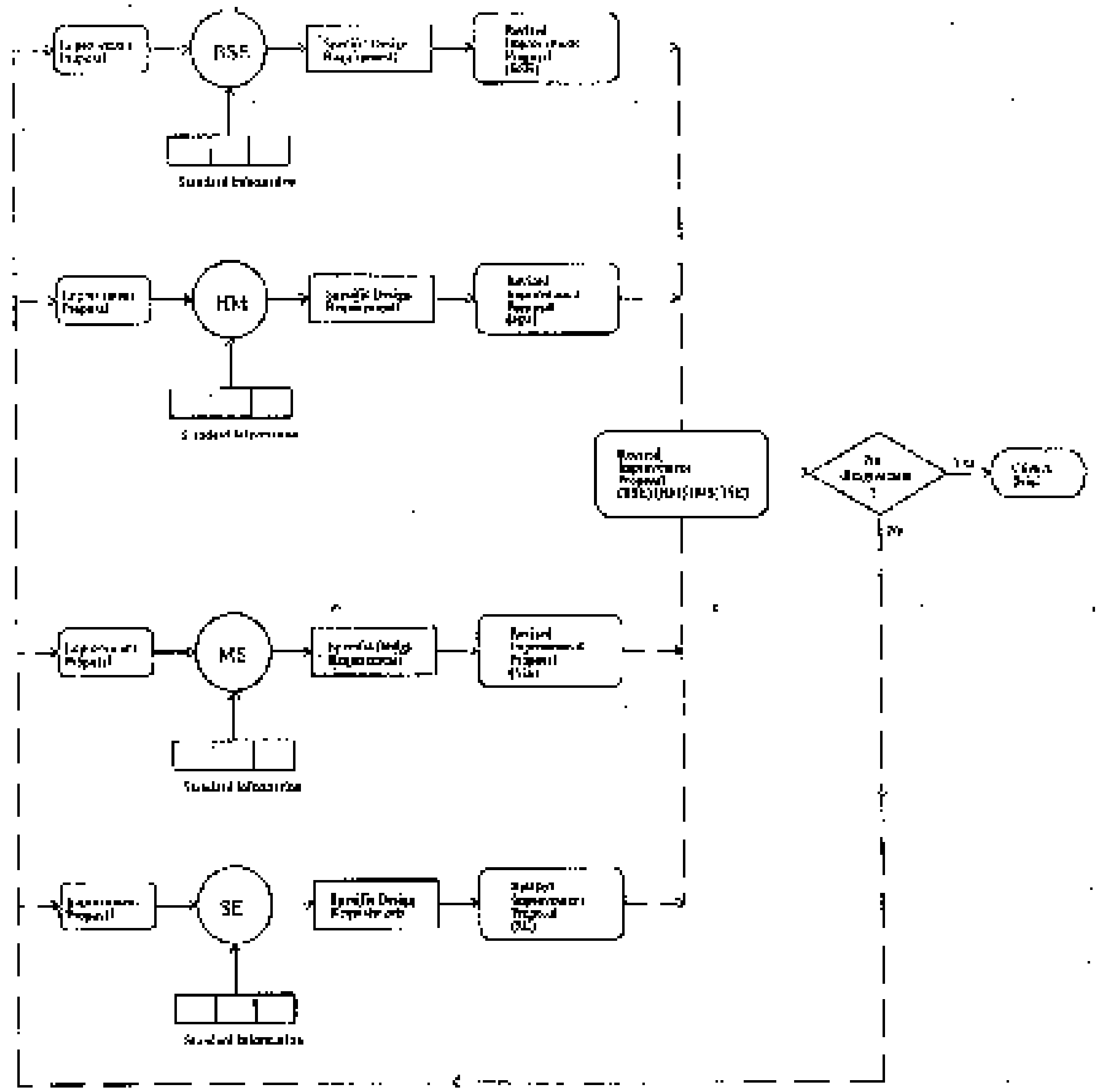

Fig. 4. The preliminary collaboration model.

to reflect the handling of design information, a preliminary collaboration model may be constructed. Obviously, different PT members may arrive at different revised improvement proposal and there should be some means to consolidate them into another updated version, which would be further elaborated. The latest version would be treated as feedback to form a close loop of the collaboration model, Fig. 4.

The suggested collaboration model conforms to the convention adopted by SSM in naming a 'purposeful activity system'. These names are known as root definitions, or core purposes. Core purpose is expressed as a transformation process in which some entity, the 'input', is changed, or transformed, into some new form of the same entity, the 'output' [4]. There are six elements, C A T W O E, that formulate the root definition:

C	customer	the victims or beneficiaries of T
A	actors	those who would do T
T	transformation process	the conversion of input to output
W	Weltanschauung	the worldview, which makes this T meaningful in context
O	owners	those who could stop T
E	environmental constraints	elements outside the system which it takes as given

The project objective of the collaboration model may be seen as the root definition: "to establish a client's brief to enhance the shopping atmosphere of the shopping center with a return rate of not less than 8% of the capital investment". The elements of the root definition are:

C	BSE, HM, MS, SE
A	BSE, HM, MS, SE
T	determines specific design requirements, check and revised improvement proposal
W	refurbish shopping center to enhance commercial viability
O	Hong Kong Housing Authority
E	8% return rate

Consequently, the root definition or the core purpose of the refurbishment project has to be realized by constructing a set of activities, which may represent the collaboration model conceptually.

5. Modes of collaboration model

The preliminary collaboration model does not suggest how the different improvement proposals could be combined into one proposal, i.e., the integration activity has to be further defined. The integrated proposal will contain three types of information items in terms of their status of acceptance by the PT members: complete agreement, no agreement and no comment. Respective basic models will process those improvement items grouped under 'no agreement' again. It is possible that after several rounds of iteration, the 'no agreement' situation could remain unchanged. Under such circumstances, it may be necessary to prioritize specific design requirements at different levels. Thus the PT will have to reach a consensus on whether active or passive modelling of the design should be adopted. Active modelling adopts the path of system or distribution-oriented design, while the passive approach concentrates more on the building fabric [6].

Alternatively, the project objective would dictate the results and end the 'no agreement' situation. As an example, the project objective "to establish a client's brief to enhance the shopping atmosphere of the shopping center with a return rate of not less than 8% of the capital investment" may be viewed as an absolute requirement. All subsequent design improvements will thus be assessed against this objective. In this instance the straightforward approach would be to cut back on any items that may yield a return rate of less than 8%. However, the anticipated rental income is dependent on a range of factors, e.g., the commercial mix in the shopping center, the overall style and layout of the stores, the economic background of the shoppers, etc. As there is no simple relationship between the rental income and improvement proposal, the calculated return rate will usually become the dominating factor in settling any 'no agreement' situation.

There is one practical aspect of the collaboration model. The four basic models identified in Fig. 4 often merge at a point after the conclusion of the improvement proposals made by respective PT members. The merging point plays a significant role in deciding the mode of collaboration. The scenario shown in Fig. 4 represents collaboration in an asynchronous manner, i.e., decisions are disjointed. In this case each PT member presents his or her design separately. Time is usually not a driver and each group has sufficient time to document the three types of information contained in the improvement proposal. However, since each PT member's presentation is only weakly connected to the other design participants a longer time period is normally required for obtaining a consensus. In this instance the asynchronous approach is less effective in resolving the "no agreement" case.

It is possible though to merge the four basic PT models at this point after the specific design requirements have been established. Were this to occur, each PT member has to modify their requirements before they conclude their improvement proposal. For instance, if the space requirement for housing a chiller plant is not acceptable to the MS, it should be possible to reduce the scope of the new central air-conditioning in order to cope with the smaller plant room. Such an agreement could be readily reached in a design meeting attended by all PT members, i.e., a synchronous approach is established. Clearly it will minimize the 'no agreement' items in the consolidated improvement proposal. However, design changes effected in this manner may be more difficult to record and thus be more prone to dispute at a later stage. It is important therefore that design changes (and the rationale behind these changes) are well documented.

The representation of the collaboration design model primarily comprises the design knowledge base (i.e., the standard information) and the reasoning of the knowledge base. Clearly, each implementation of the model should result in refinement or revision of the variable data in order that it may cope with changing design requirements with a view to achieving the required level of flexibility. While Checkland's root definition has provided the conceptual basis for the development of the collaboration model, the flexibility of applying Pohl's intelligents approach in tackling less-well-structured problems is reviewed in contemplation of a computer-aided design environment.

6. Agents and flexibility

Pohl advocates the importance of providing flexibility in the user-interface in order to facilitate the human–computer partnership for tackling complex problem [3]. The flexibility may be achieved by building computer-based agents in the process model such that solutions may be evolved interactively. The relation between the degree of flexibility and the complexity of a problem is not indicated in Pohl's work. Clearly the effort necessary to develop computer-based agents that can communicate with other agents computer-based or human is quite significant and has to be justified against the complexity of the decision-making problem. In case of a refurbishment project, flexibility is mostly needed for the tracking of the design decision and subsequent refinement of the collaboration model. Flexibility may also be perceived as the availability of any sophisticated computer system that provides intelligent means to obtain results of building services engineering calculations, such as the recognition of CAD objects (i.e., high level representation of design data) for automated generation of air-conditioning ducts and pipes. However, it is not critical in enhancing the effectiveness of the collaboration design process as a whole because it constitutes only a relatively small portion of the entire collaboration work (less than 10% of the total working time approximately).

Part of the problem which has already been defined for the shopping center refurbishment collaborative model, i.e., the human agents (BSE, HM, MS and SE) and the standard information needs to be well structured. It is also understood that interrogation of the standard information knowledge base by PT members may be an extremely complicated process. Following this argument it may be said that flexibility in organizing design information (and subsequent changes should these be required) may play a more important role in comparison with the flexibility arising from the generation of new engineering data. Where this occurs it may not be of the first priority to establish a computer-based agent to carry out such functions as the interrogation of knowledge bases intelligently. The more pragmatic approach is to provide an information organizer that may be able to capture and retrieve the decisions made by the PT members under a computer-aided environment. Such a tool should preferably be flexible and efficient in terms of the resources required for development.

The specific design requirement and improvement proposal consists essentially of lists of design items.

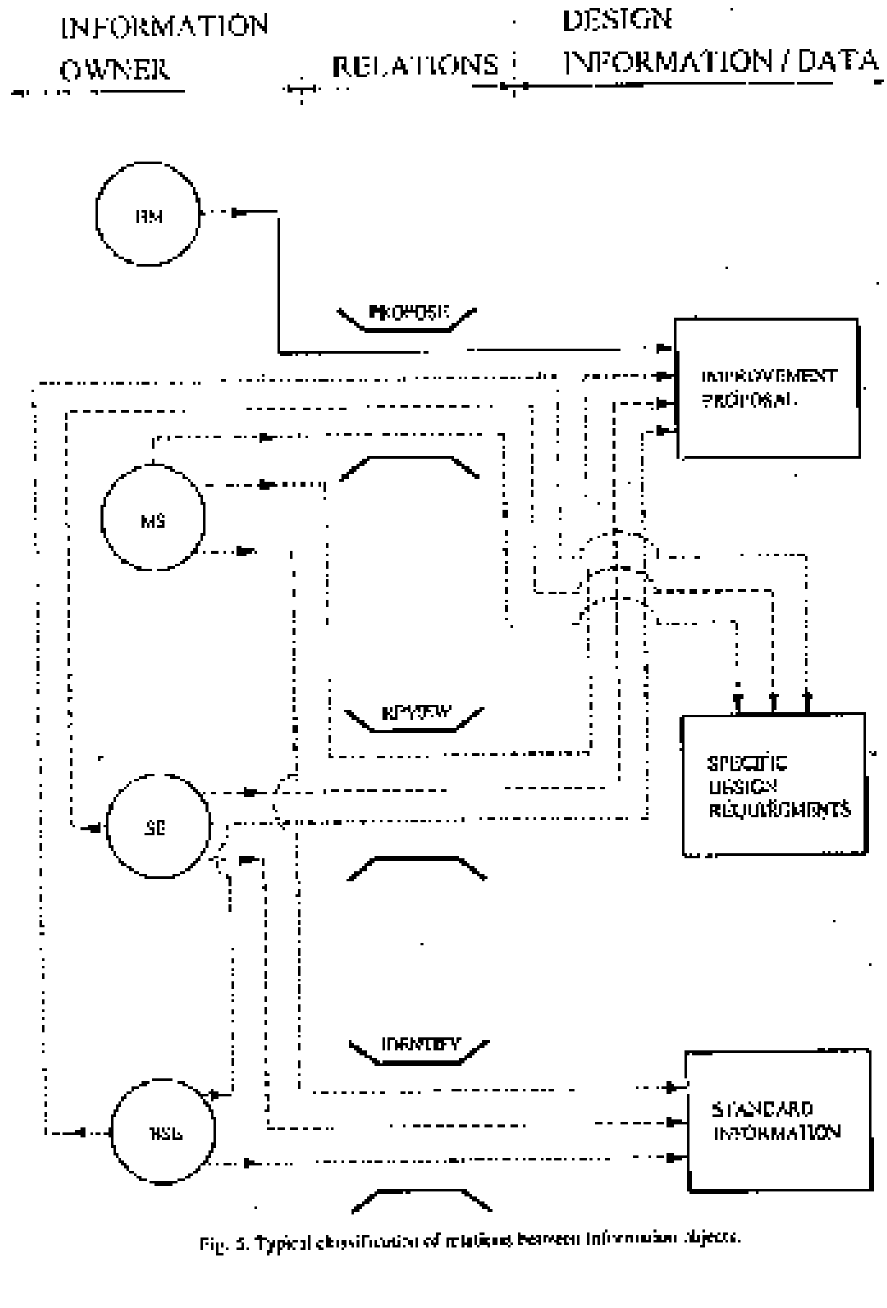

Fig. 5. Typical classification of relations between information objects.

which are grouped together not necessarily with any sequential relationship. They serve the purpose of providing authorization for the subsequent development of the tender specification and construction details. (The latter are similar to the role of the building codes and regulations.) As such, it may be argued that specific design requirement and the improvement proposal (and subsequently the client's brief) could be readily represented as a hypermedia model. It has been demonstrated that hypermedia is appropriate for the development of a design tool for rule-based building services engineering at the preliminary design stage [7]. The construction of hypermedia models for the specific design requirements and improvement proposal is a logical extension of the concept pertaining to the rule-based hypermedia model for building services engineering design. By virtue of the modularity of hypermedia models, the flexibility to cope with the unpredictable request for subsequent design changes may be feasible, i.e., additional modules could be connected to the existing hypermedia model without any significant input to rearrange the architecture of the computer programme. In fact, hypermedia has been considered as an appropriate medium for representing the content as well as the process of collaboration [8].

7. Hypermedia model

By itself, hypermedia is unable to change the design. It also lacks the tool to communicate directly with many other computer systems. However, its ability to organize information in a nonlinear manner resembles the way a designer typically posts his ideas as his design evolves. The application of hypermedia to the preliminary design of rule-based building services engineering design suggests a feasible approach to tackle a less-well-structured problem in a computer-aided environment. With regard to the refurbishment project the technique for developing a hypermedia model may be somewhat different in that a multiuser environment has to be considered. A hypermedia model is being developed based on the data structure as outlined in Fig. 4. Rule-based preliminary building services engineering design concepts will be applied and modified as required. Typically, the three primary information elements will be further broken down into various information items or objects, and their relationship with the elements of the root definition will be defined. It has been shown that by identifying and classifying the different types of this relationship, the effectiveness of retrieving information and updating of the hypermedia model can be greatly enhanced [7].

In hypermedia, information may be represented and carried in the form of nodes as well as links between nodes. Nodes and links may be seen as objects that could be created, copied, moved, modified and destroyed. In the case of a refurbishment design model, the three primary information elements which define the design information/data belong to the 'T' or 'transformation process' as described in the root definition. On the other hand, the BSE, MS, SE and HM play the roles as 'C' or 'A', i.e., 'customer' or 'actor'. It is observed that they are accountable for the primary information elements belonging to their respective disciplines, i.e., they are owners of such design information/data defined under the three primary information elements. There is no active relation between the primary information elements (though the specific design requirement is a function of standard information). Also, the relations between the information owners will not have any significant meaning unless they are connected to the design information/data. As a result, the remaining relations that may be significant for consideration are the actions that the owners will take with regard to the design information/data. The owner may propose, review or identify a set of design information/data, Fig. 5. It can be seen that the agreement between the various owners may be reflected by checking the 'PROPOSE' relation through which all owners point to the same version of 'improvement proposal' or in hypermedia term the same information object.

Once again the strength of adopting the classification of relations between information objects for facilitating the information flow and subsequent retrieval of design decision has been illustrated. Ongoing work is being carried out to identify strategic relations of the collaborative design process. The configuration arising from these relations are being constructed and tested against the performance standard of the existing system for handling collaborative design information.

8. Conclusion

The process for the development of the client's brief in respect of the role played by the BSE for shopping center refurbishment has been outlined. The proposed model has identified the need for collaboration between members of the project team. The need for a suitable method to map the flow of design information in an iterative manner is made. It is also observed that the choice of the point where the basic models could merge has a significant impact on the mode of collaboration, i.e., synchronous vs. asynchronous. In this way the requirements of the BSE (and other members of the PT) in solving complex problems may be considered and applied wherever appropriate. The primary informational elements of the collaboration model have also been identified and their relevance to the framework of collaboration has been analysed.

Critical examination of the informational elements suggest that sophisticated computer systems such as 'agents' may not be necessary in order to provide the flexibility to handle complex problems. The adoption of hypermedia to model a part of the collaboration process may provide sufficient flexibility commensurate with the size of the problem. This argument will be further verified subsequent to the completion of the hypermedia refurbishment model currently under construction.

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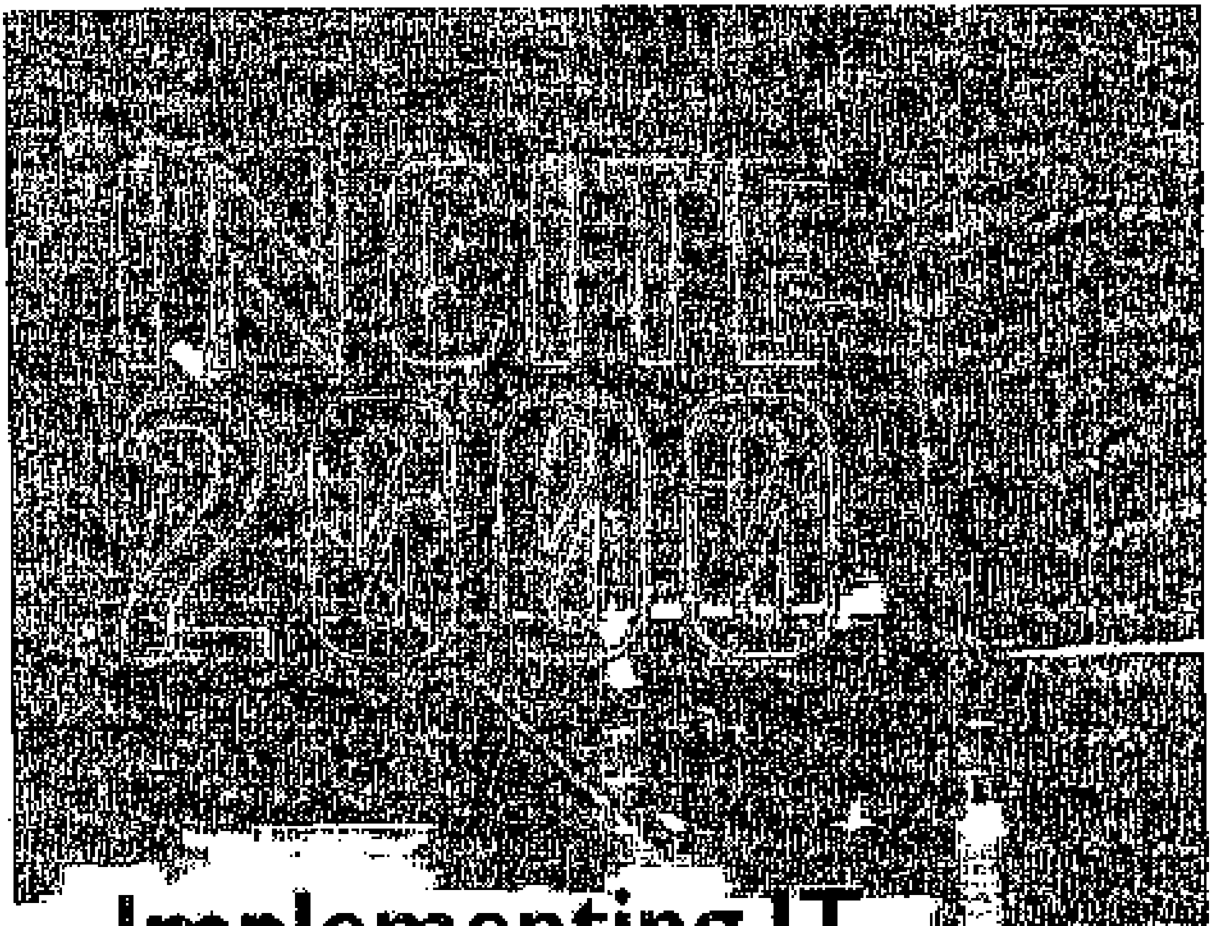

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COLLABORATIVE DESIGN: A PROCESS MODEL FOR REFURBISHMENT

LEE Yan-chuen, MPHIL AND J. D. GILLEARD, PHD
Department of Building Services Engineering
The Hong Kong Polytechnic University

Abstract. Collaborative design related to refurbishment projects is a complex process. The number of parties involved compounds this complexity. So too the iterative nature of design whereby information flow and decision rules are typically non-linear. Hypermedia is therefore suggested as an appropriate medium as well as a tool to model this process. By reviewing the refurbishment of mechanical and electrical (m&e) equipment within a shopping center the appropriateness of a hypermedia paradigm is examined. In this way primary information elements and relations between such elements are identified. These form the basis for the development of the hypermedia model described in this paper.

1. Introduction: The Problem

The model attempts to mimic the procedures for developing a client's design brief. The brief may be said to reflect the needs, rules and design guides of various project team members. Flexibility in coping with change is an important feature of the model. In addition, whenever change occurs tracking (record keeping) these design changes along with background information, arguments and justification etc is essential. Evidence indicates that design changes for refurbishment projects occur in an unpredictable manner. This is frequently due to a number of factors, e.g., lack of suitable design data at the early design stage; insufficient "condition survey data" relating to the existing m&e equipment; and inadequate information on the condition of the building fabric. Ineffective communication between the client and project team members may also result in misunderstanding of the client's need resulting in abortive design work.

Collaborative design process is understood as the integration of distributed work by information sharing rather than by conventional data exchange. The product modeling approach has been widely accepted as the methodology to define the data aspect of business objects to facilitate exchange of design information, which is typically represented by the Industry Foundation Class (IFC) developed by the International Alliance of Interoperability. The difference in the scope as well as the concepts between the IFC approach and hypermedia model in respect of the strategy for the exchange of design information will also be discussed in this paper.

2. Collaborative Design vs. Information Sharing

The basic collaboration model has been identified (Gilleard and Lee 1998). The project team (PT) normally comprises building services engineer (BSE), housing manager (HM), maintenance surveyor (MS) and structural engineer (SE). Further study of this model suggests that the process of collaboration as well as the results of this process is focused at Node '[illegible]' of the model, Figure. 1. In real situation, each PT member may present his Improvement Proposals in a design meeting and exchange them with other PT members. Essentially they have started a series of activities in sharing design information. The PT members may be collaborating to arrive at a consensus or merely uttering their own ideas with no agreement at all. In most cases, they may have partial agreement on the improvement proposals. Clearly it is not adequate to document what have been agreed only. Resolving the differences between PT members to arrive at a complete agreement effectively is hinged on the understanding of the rationale behind those disagreed improvement items. These information regarding disagreement are very often difficult to document and as a result they are not readily retrieved by other members.

Under the hypermedia environment, Node '[illegible]' may be represented by a framework or matrix which co-ordinates the different improvement proposals against respective information owners (i.e. PT members) for various major improvement items, Figure. 2. Further information supporting respective proposals could be readily retrieved through hyperlink and these may include site sketches, photographs, drawings or even animation for illustration purpose. Although hypermedia is flexible in extending its nodes and links to 'rest' more information, it is crucial that a framework of the collaboration model has to be defined. PT members may be easily lost when they collaborate or share information within the hypermedia collaboration model, which will gradually increase in its size and complexity. On the other hand, designated areas or means of access have to be defined under this framework to let individual member to input their design intent or arguments. It conforms to the hypermedia design concepts regarding "the distinction between structuring "on the large" and authoring "on the small'" (Strietz 1995).

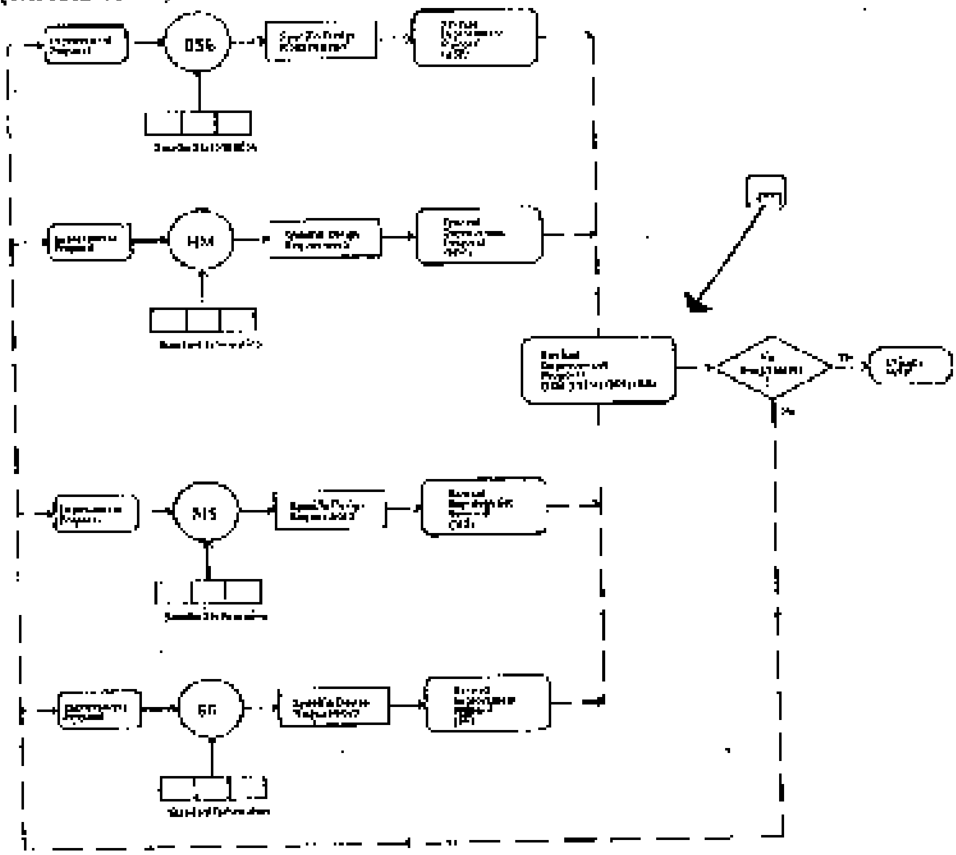

Figure 1. The Basic Collaboration Model

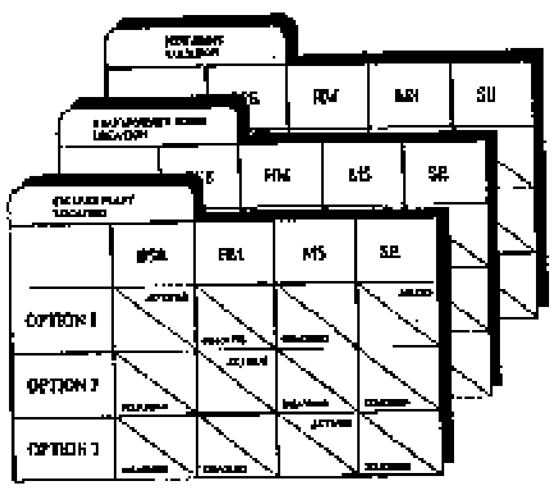

Figure 2. Conceptual Hypermedia Model for Collaborative Design

3. Control of Collaborative Design Process

The iteration process as shown in Figure 1 will stop only when there is a complete agreement among members. Such a scenario of total agreement is rare in practice. Typically, transforming the disagreement between members into different design options may conclude the development of a client's brief. Different design option may result in a different project cost. Typically, options that incur a higher cost are deleted from the client's brief. However, if a specific option(s) is/are considered by the client to be essential although costly these may also be included. For example, the client's design team may choose relatively expensive finishes that are considered to enhance the aesthetics / attractiveness of the shopping centre. In this way the additional cost may be justified on commercial grounds on the basis that a more pleasing atmosphere will attract more customers to the shopping centre. Similarly the designer / client may favour greater expense on the false ceiling, lighting fittings, air grille or diffusers based on commercial judgement providing of course that the tender price does not exceed the project budget. In such instances the project team may go ahead to include these provisional items. In this connection, criteria have to be defined, at a certain stage of the design process, to conclude the iteration in order to allow the PT members to decide which items have to be included in the client's brief. The problem is who should take the lead under such a multi-disciplinary relationship. It is entirely a management issue that could not be possibly resolved by a computer.

As far as the hypermedia model is concerned, clearly each member is a reader of the model and at the same time an author as well. In traditional literature and writing the author will have full control over the development of the text. However, in hypermedia, the roles of an user are evidently twofold. "hypertext...places reading and writing in a connected and overlapping terrain, thus providing a forum in which reading and writing can be reconceived in such a way that these traditionally separate acts begin to partially coalesce." (Snyder 1996). It is inevitable that the role of an author overlaps with that of the reader under the collaborative design environment. In other words, the behaviour of a hypermedia model may behave differently as seen by a PT member as reader or as author.

The illustration as shown in Figure 2 is taken as an example. Under the improvement item of chiller plant location, the BSE is the author of Option 1 while other PT members are readers. Similarly, the HM and MS play the role as author in Option 2 and Option 3 respectively. Under such circumstances, the hypermedia model functions as an agent to document (i.e. to keep an account of) and organize the decisions that have been made against respective design options. Clearly the changing of roles of individual PT members under different design options complicates the decision making process as the control authority is no longer vested in one person only.

The technique of delaying the decision -making by putting the "disagreed option" as provisional items in the contract may not be applicable to critical items that have significant impact on the overall design. The decision of whether central air-conditioning should be provided to a refurbished shopping centre is an example. Therefore, it is logical to break down the problem into sub-problems and classified them into different groups according to their significance with regard to overall design of the project. The chance of arriving at a agreement among PT members with regard to one group should be higher than that of several groups for a given time constraint.

4. Alternative Approach to Resolve Disagreement

The different groups of sub-problems or design options are set at different levels that may be ranked according to the extent of their relevance in respect of the whole project. There are at least four levels that could be identified for a typical refurbishment project, Figure 3. The highest level is the objective of the project that is a conceptual one in contrast with those at the lower level ones such as the choice of lighting fittings. Consequently, collaboration between PT members to achieve agreement may be carried out from the top level downward under normal circumstances. For instance, the chiller plant location cannot be considered unless the requirement of providing central air-conditioning to the shopping centre has been determined. Occasionally the sequence may be reversed; i.e. the availability of a suitable chiller plant location has to be confirmed before the requirement of central air-conditioning could be defined. Such a scenario may arise from the findings during the feasibility study stage that available space for plant area will be very limited. Clearly such a back tracking from the lower level to the higher ones will undermine the effectiveness of the project team in concluding the client's brief.

Besides less effective in the decision-making process, the major shortcoming of the non-sequential mode of design development is that some critical design decision could be overlooked. A missing step in the process of client's brief development may imply that part of the refurbishment work is carried out without authorization from the client. If the client refuse to accept the work and instruct the project team to redesign the portion of the project in question, extra cost and time will be incurred subsequently. Clearly these options at different levels are inter-related and hypermedia may provide the necessary links to reflect the significance of design information structure. In principle, any improvement item should be connected to a corresponding item one level above it. When the project team wish to conclude the client's brief, they may interrogate the hypermedia model to highlight any "unconnected" items. Evidently the conceptual basis of constructing the relations between those items or design requirements at different levels has to be meaningful in the way that they would associate with the same system, e.g. chiller plant location should be connected to central air-conditioning under the major requirements.

Level 1	**Improvement Objective.**
Level 2	**Major Requirements: new central air-conditioning systems, additional transformer, additional escalators, additional retail space.**
Level 3	**Locations and scope of work: location of chiller plant, shopping area to be air-conditioned, location of new transformer house, location and quantity of new escalators, location and area of new retail space.**
Level 4	**Sizing of plants and systems, materials, critical construction details.**

Figure 3. The four-level configuration of the hypermedia model

5. Design Changes

It has been argued that design changes for refurbishment projects occur in an unpredictable manner. Changes may take place any time from the preliminary design stage to the final completion of a project. However, for a particular design change, it could result in a different time and cost implication with respect to different stages of a project. Depending on the magnitude of the impact on time and cost pursuant to design changes, a project may be seen as three major stages, i.e. pre-tender stage, tendering stage and construction stage. Design changes taking place during pre-tender stage will not incur any time and cost loss practically except extra cost due to additional scope of work. The situation is similar for the tendering stage unless the scope of the change is so large that re-tendering becomes unavoidable. Changes during the construction stage are most unfavourable in terms of time and cost control, and unfortunately it is the most critical challenge that the project team has to face. Obviously the project team has to cope with the change with time and cost implication kept to a minimum. On the other hand, if the time and budget constraints are likely to be exceeded arising from the change, the project team is obliged to justify the case to the client that the change in question may not be entertained. Under these circumstances, it has to be demonstrated that to what extent the hypermedia model could facilitate the project team to manage the design process in such a way that the project would be carried out within constraints.

The conceptual hypermedia model of the design process as shown in Figure 3 is considered again. For instance, the area of the shopping centre to be provided with air-conditioning has to be increased during the construction stage. This improvement item is classified under Level 3 of the model. The scope of the proposed change is checked at Level 3 in the first instance. It is connected to the item of providing central air-conditioning as stipulated in Level 2, which is also consistent with the improvement objective laid down in Level 1. Having satisfied himself with regard to the authorization of design requirements by navigating "upstream" of the model, the project BSE may proceed to solicit the agreement of other PT members at this level similar to the exercise that has been carried out during the pre-tender stage. If the revision of client's brief could be concluded, he may go "downstream" to check the item of air-conditioning plant sizing at Level 4. Clearly the effectiveness of the PT members to respond to design changes is dependent on the readiness of the hypermedia model to provide access to key design information or history. It can be shown that with the appropriate planning of the levels of the framework as well as the hyperlinks constructed strategically, the unfavourable impact to the progress of a project under unpredictable changes could be minimized.

6. Collaborative Design from a Different Perspective

The collaborative design process as discussed is studied on the perception that all the professionals of the project team are in-house staff, i.e. all belong to the same organization. The definitions of the various improvement items could be readily comprehended by all PT members who should have cultivated mutual understanding subsequent to their participation in various projects as a team. Clearly the description of an improvement item should be consistent at different levels of the hypermedia model and fully recognized by PT members of different disciplines. Otherwise, the searching of information and corresponding navigation tactics could be confused as a result of inconsistent terminology. In other words, only one set of modeling language should adopted. Clearly there are gaps in information sharing in the construction industry as a whole. Solutions are being developed to bridge the gap with the recognition of potential business benefits by professionals in industry.

Typically, the Industry Foundation Classes, IFC, have been developed by the International Alliance for Interoperability, IAI, to provide for data exchange and sharing capabilities for the building and construction sector of the industry (Liebich and Wix 1998). In brief, the IFC provides the framework and techniques for information exchange by describing "that" this information is and "how" it is exchanged. However, in reality the construction domain knowledge lies outside the focus of the core product and process modeling activities such as IAI (Lockley 1998). As such, as far as the collaborative design model is concerned, the modeling language could not be readily formalized under the IFC framework. Nevertheless, the model should be IFC proved in the long run when the scope of collaborative design activities will be extended to other parties such as the contractors as well as professionals of other consultancy firms as a result of outsourcing. It may be pre-matured that the collaborative design model for in-house application should be IFC compliant in consideration of the very "localized" situations for which the real benefit of IFC has yet to be demonstrated. Indeed, there are comments that there is still not enough hard evidence (of real and significance benefit) coming from real project, more evidence is needed to fully convince industry to continue to support the development of the IFCs (Wix 1998).

7. Conclusion

The design process of the refurbishment of a shopping centre has been reviewed. A conceptual hypermedia model of this process is suggested. It is observed that the changing roles of the project team members at different stage of the design process under different design topics correspond to the dual roles of an user of hypermedia, i.e. reader as well as author. The cognition of the dual roles gives rise to the restructuring of the configuration of the hypermedia model. Decision-making activities are broken down into a four-level model that is seen as a more effective model in terms of flexibility to cope with unpredictable design changes. International standards in information exchange such as the IFC have been considered. Adoption of its framework to the collaborative design model is not appropriate at this stage, which should be deemed as another major research topic to be pursued separately. The collaboration model being developed basically describes the activities of an in-house design team. Further research work will focus on the generation of a glossary of the definitions of the activities such that the model may recognize and provides effective guides for navigation by PT members. Standardization of such a glossary against international standards may not be fruitful because different in-house team may have different working cultures.

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