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A generic finishes database for healthcare facilities.

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A GENERIC FINISHES DATABASE FOR HEALTHCARE FACILITIES

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This paper is the fifth in a series reporting on-going research within a Department of Health (DOH) funded research project to develop a novel decision support system for the optimal selection of finishes for healthcare facilities. The system has been developed by integrating a recently developed extended whole-life costing (WLC) application with the resource database reported in this paper. The database has been designed and implemented in MS Access® to accommodate finishes' whole-life cost and time data and other data categories including quality, performance and other relevant non-financial data. The database structure has been designed on the basis of an in-depth analysis of the requirements of effective WLC decision-making during the design stage, the special needs of the healthcare environments, and the limitations of previous efforts to utilize databases to facilitate whole life costing. The database relational structure is explained and the data types and descriptions of fields of various tables are reported. In addition, a user friendly input form designed to facilitate editing data is included. Finally, directions for further future research are introduced.

Keywords: design decisions, finishes, healthcare, integration, whole-life costing.

INTRODUCTION

In a previous paper (Kishk *et al.*, 2006a); an integrated approach for the selection of hospital finishes is outlined using simple process flow diagrams. In a subsequent paper (Kishk *et al.*, 2006b); an innovative application for the optimal selection of hospital finishes has been developed based on this framework. The logic of the application is designed around two generic whole-life costing (WLC) databases. The first is a resource database that houses data for several options for various finishes suitable for various spaces of hospital building. In this way, a meaningful exercise can be undertaken to decide upon the optimum finish alternative. Then, the selected finish alternatives are stored in the project database for later use in the effective management of the building over its life cycle. The second database is a project specific database which accommodates WLC data for the selected optimum set of finishes to be used throughout the hospital building life cycle.

The objective of the research work reported in this paper was to develop the generic resource database. In the following two sections, the methodology is reported and the main requirements of the database structure are outlined, respectively. Then, the

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detailed design of the database is reported. Next, testing and validation of the system is reported in some detail. Finally, directions for further research are introduced.

METHODOLOGY

The main work components in developing the system are as follows:

- Potential user groups for the project outputs, including representatives of NHS Trusts, PFI Consortia, designers, contractors and other stakeholders have been contacted and an appropriate sample recruited to the Steering Group.
- Finishes being used in for a variety of purposes in a variety of healthcare environments has been identified.
- Relevant selection criteria for these finishes have been also identified, including financial and non-financial criteria. Questionnaires have been administered to relevant managers in hospital trusts and suppliers and an extensive review of the literature, specifications and other official documents has been conducted.
- The resource database has been developed.
- An extended WLC application has been developed (Kishk *et al.*, 2006b).
- The system is developed by integrating the decision-making application and the two databases through an interactive interface.
- Test and validate the developed system.

KEY REQUIREMENTS

The space concept

A hospital building can be conveniently defined as a collection of spaces. Within a healthcare environment, the use of different spaces varies from office and general use to very high wear circulation areas and indoor ‘streets’, to ward areas, to highly specialized theatre areas. Within many of these spaces a range of issues distinguishes healthcare environments from most other building types and needs to be considered in the development of the proposed WLC tool. Perhaps the most important of these issues relates to the control of infection. Hospital environments in particular are subject to spillage of a range of potentially dangerous substances, in areas of general use such as circulation areas, as well as in wards. Here the choice of finishes is not only important in determining cleaning regimes, but may for example incorporate resistance to the spread of infection through the use of antimicrobial agents, fungicides etcetera, as additives to applied finishes (Gelder, 2003). Space has also has an effect on the selection of the finishes in a hospital, especially if rooms are smaller and more cellular (Laing *et al.*, 2006). In other words, selection criteria and their relative weights of importance may be different for various spaces.

To undertake a WLC analysis of the space, it is necessary to breakdown costs into its constituent cost items. These cost items should be individually identified so that they can be distinctly defined and estimated. Adopting the space concept means that an elemental cost format is required. This format relate well with the kind of decisions that are made at various design stages as noted by Kirk and Dell’Isola (1995).

Generic cost categories

By definition, cost data required for WLC purposes include initial costs and future follow-on costs that may include maintenance and repair costs, operating costs, replacement costs, disposal costs and resale values. The grouping of cost items into these categories allows producing various planning schedules and profiles and cash flow diagrams during various stages of the project. Thus, it is crucial to include the generic category of each cost item in the CBS.

Time horizons

The times in the life cycle of the project when the cost-associated activities are to be carried out should also be recorded. These time horizons are crucial in the calculation of whole life costs. They are also necessary to develop various profiles and diagrams mentioned above. Thus, it is required to add a recurrence code to make a distinction between one-off, annual recurring, and non-annual recurring activities.

Non-financial data

The design or component selection decisions can often be taken based on non-financial factors, e.g. strength of materials, fire-protection, hygiene, health and environmental protection, safeguarding of use, sound isolation, energy saving and thermal isolation, durability and utilization (Bogenstatter, 2000; Kishk, 2002). These arguments are especially true in the complex environment of healthcare buildings. Hospital design is notably very complex, which makes the selection of finishes within a hospital also complex (Kishk *et al.*, 2007). In a previous paper (Laing *et al.*, 2006), major non-financial selection criteria for hospital finishes have been identified through meetings with strategic team members in the industry and through a literature search of, for example, health building notes (HBNs). The survey has proved a useful tool in determining the ranking of various selection criteria.

Other crucial data requirements

Al-Hajj (1991) has shown that building-size and number-of-storeys as well as design-purpose influence the running costs of buildings. Even, different buildings used for the same purpose but with different physical aspects will incur different costs. Thus, the range of applicability of each cost for various building types, sizes, heights and location should be recorded as well. In this way, cost data can be interpreted with physical data and the type of building that incurred them.

Data normalization

Hobbs (1977) and Flanagan *et al.* (1989) stressed the importance of the hours of use and occupancy profile as other key factors especially for public buildings such as hospitals and schools. This view was supported by Martin (1992) who showed that users and not floor-area had the greatest correlation with costs-in-use of hospitals.

Thus, other data normalization methods, or rate codes, should be also employed to depending on the basic nature of the cost under consideration. Another justification of this requirement is that no single source would provide the data for the database as discussed in the first part of this report. Examples of the required rate codes include cost per element area, per element length, per element volume, per gross floor area, per gross surface area and per building use.

Data uncertainty

By definition, uncertainty is endemic to WLC. The inclusion of the effect of the building use, size, type and location as discussed above and the utilization of different rate codes for various cost elements would eliminate some of the uncertainty in cost and time data. However, there is still a need to include the variability of cost and time data into the database. This variability can be represented by a distribution rather than by a single value. According to the type of uncertainty in the data item, either a probability distribution function (PDF) or fuzzy number (FN) is used (Kishk, 2004). For example, if multiple records of a data item for the same building type and size exist, the mean value, standard deviation, minimum and maximum values are recorded.

DETAILED DESIGN OF THE DATABASE

Based on the requirements outlined in the previous section, the resource database has been designed. The relational structure of the database, names of tables and links between tables are outlined in Figure 1. As shown, the database design was kept as general as possible. Data are stored in three main tables:

- the space options table;
- the option activities table; and
- the activities cost items table.

These are explained in the following subsections.

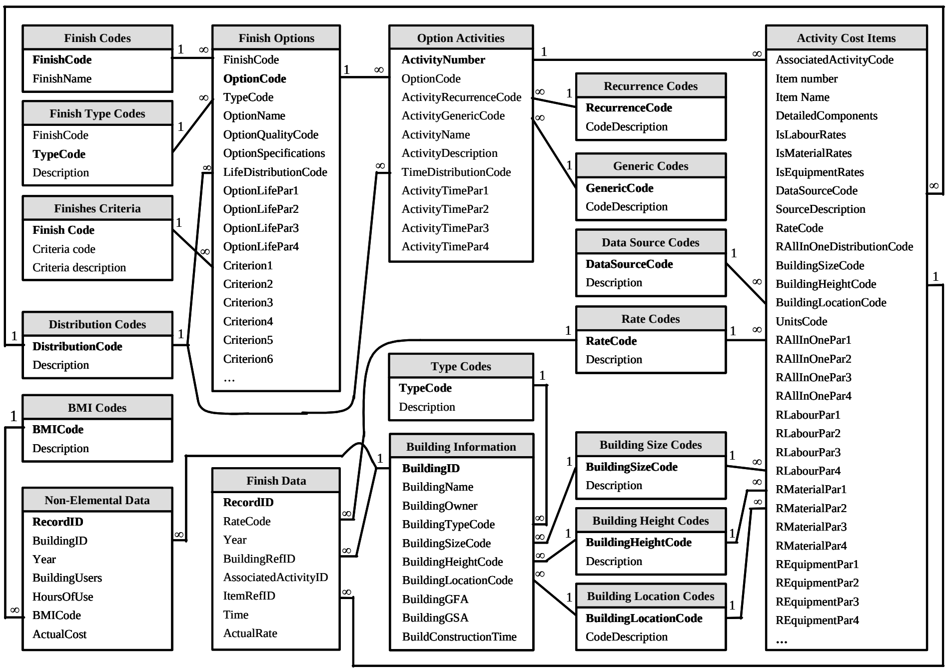

Figure 1: The resource database relational structure

The finish options table

The finish options table stores the basic data about available options of each finish. As shown in Figure 2, this table includes 27 fields to define the following 8 characteristics of each option.

- The *FinishCode* field stores the code of the option as defined in the 'Finish codes table' (Table 1), e.g. '1' for a floor finish.

- The *OptionCode* field is an automatically generated number that uniquely identify each option and is used to link the table to other tables in the database.
- The *TypeCode* field stores a code that uniquely defines an element subtype.
- The *OptionName* field stores the name of the option.
- The *OptionQuality* field stores the quality code of the option (see Table 2).

FinishOptionsMainTable : Table

Field Name	Data Type	Description
FinishCode	Text	Code of the Finish
OptionCode	AutoNumber	ID of the finish option (generated automatically)
OptionName	Text	Name of the option (maximum of 50 characters)
FinishTypeCode	Number	Generic Type of the Finish
OptionQualityCode	Number	0, 1 or 2 for Low, Medium or High, respectively
OptionSpecifications	Memo	Detailed specifications of the option.
OptionLifeDistributionCode	Number	0, 1, 2, 3, 4 or 5 for crisp, TFN, TrFN, Normal PDF, trapezoidal PDF or triangular PDF, respectively
OptionLifePar1	Number	First parameter for the option life.
OPtionLifePar2	Number	Second parameter for the option life.
OptionLifePar3	Number	Third parameter for the option life.
OptionLifePar4	Number	Fourth parameter for the option life.
Criterion1	Yes/No	Criterion number 1
Criterion2	Yes/No	Criterion number 2
Criterion3	Yes/No	Criterion number 3
Criterion4	Yes/No	Criterion number 4
Criterion5	Yes/No	Criterion number 5
Criterion6	Yes/No	Criterion number 6
Criterion7	Yes/No	Criterion number 7
Criterion8	Yes/No	Criterion number 7
Criterion9	Yes/No	Criterion number 8
Criterion10	Yes/No	Criterion number 9
Criterion11	Yes/No	Criterion number 10
Criterion12	Yes/No	Criterion number 11
Criterion13	Yes/No	Criterion number 12
Criterion14	Yes/No	Criterion number 13
Criterion15	Yes/No	Criterion number 14
Criterion16	Yes/No	Criterion number 15

Figure 2: Data types and descriptions of fields of the finish options table

Table 1: The finish codes table.

Code	Finish
1	Flooring
2	Walling
3	Ceilings
4	Doors
5	Windows
6	Furniture and fittings

Table 2: The quality codes table

Quality Code	Code Description
0	Low quality
1	Medium quality
2	High quality

- The *OptionSpecifications* field stores the detailed specifications of the option.
- The life expectancy of the option, like all uncertain variables in all tables, is defined by 5 fields. The first field, *OptionLifeDistributionCode*, stores the distribution code as defined in the Distribution codes table (Table 3). The other four fields stores 4 parameters that define the distribution as shown in Table 4.
- The *Criterion1*, *Criterion2… Criterion16* fields specify the applicability of the option to various non-financial criteria for the finish as defined in the finishes criteria table.

Table 3: The distribution codes table.

Distribution Type	Description
0	Crisp (Certain)
1	Triangular Fuzzy Number (TFN)
2	Trapezoidal Fuzzy Number (TrFN)
3	Normal PDF (NPDF)
4	Trapezoidal PDF (TrPDF)
5	Triangular PDF (TPDF)

Table 4: Meaning of the distribution parameters

Type	Parameter 1	Parameter 2	Parameter 3	Parameter 4
Crisp	Certain value	N/A	N/A	N/A
TFN	Minimum value	Likeliest value	Maximum value	N/A
TrFN	Minimum value	Likeliest value 1	Likeliest value 2	Maximum value
NPDF	Mean value	Standard deviation	Minimum value	Maximum value
TrPDF	Minimum value	Likeliest value 1	Likeliest value 2	Maximum value
TPDF	Minimum value	Likeliest value	Maximum value	N/A

The option activities table

The option activities table stores the basic data about the activities of the element options stored in the element options table. As shown in Figure 3, this table includes 11 fields to define the following 7 characteristics of each activity.

Field Name	Data Type	Description
OptionCode	Number	Select an option using this combo box
ActivityGenericCode	Number	0=initial; 1=maintenance; 2=replacement, 3=operating;4=demolition ; 5=resale … etc
ActivityNumber	AutoNumber	
ActivityRecurrenceCode	Number	0=single future; 1=annual; 2=non-annual recurring; 3=N/A
ActivityName	Text	Text to describe the activiy(ies) associated with cost item
ActivityDescription	Memo	Put here any other information regarding this activity
ActivityTimeDistributionCode	Number	0, 1, 2, 3, 4 or 5 for crisp, TFN, TrFN, Normal PDF, trapezoidal PDF or triangular PDF, resp
ActivityTimePar1	Number	First parameter for the activity time.
ActivityTimePar2	Number	Second parameter for the activity time.
ActivityTimePar3	Number	Third parameter for the activity time.
ActivityTimePar4	Number	Fourth parameter for the activity time.

Figure 3: Data types and descriptions of fields of the option activities table

- The *OptionCode* field stores the option code to which the current activity belongs. This field links the table with the element options table.
- The *ActivityNumber* is an automatically generated number that uniquely identify each activity and is used to link the table to ‘activities cost items table’.
- The *ActivityRecurrenceCode* field stores the recurrence code of each activity as defined in the recurrence codes table (Table 5).

Table 5: the recurrence codes table

Code	Description
0	Not Applicable
1	Annual Recurring
2	Non-annual Recurring
3	One-Off

- The *ActivityGenericCode* field stores the generic code of each activity as defined in the Generic Codes Table (shown in Table 6).

Table 6: The generic codes table

Code	Description
0	Initial
1	Maintenance
2	Replacement
3	Operating
4	Disposal
5	Resale

- The recurrence time of the activity, like all uncertain variables in all tables, is defined by 5 fields. The first field, *ActivityTimeDistributionCode*, stores the distribution code as defined in the ‘Distribution Codes Table’ (Table 4). The remaining four fields, *ActivityTimePar1*, *ActivityTimePar2*, *ActivityTimePar3*, and *ActivityTimePar4* store the 4 parameters that define the distribution as shown in Table (4).
- The *ActivityName* field stores the name of the activity.
- The *ActivityDescription* field stores additional information about the activity.

The Activity Cost Items Table

The activity cost items table stores the data about the cost items of the activities stored in the option activities table. As shown in Figure 17, this table includes 34 fields to define the following characteristics of each activity.

Field Name	Data Type	Description
AssociatedActivityCode	Number	Reference Code of the Activity associated with this cost item
ItemNumber	AutoNumber	Automatic reference number for this cost item
DetailedComponents	Number	0 for all-in-one-rates, 1 for detailed rates
IsLabourRates	Yes/No	Is labour rates given (applicable for detailed rates only)
IsMaterialRates	Yes/No	Is material rates given (applicable for detailed rates only)
IsEquipmentRates	Yes/No	Is equipment rates given (applicable for detailed rates only)
DataSourceCode	Number	Data Source Code (0=Historic data; 1=price books; 2=subjective; ...).
SourceDescription	Text	Description of the data source; e.g. name of the price book.
RateCode	Number	The rate code of the cost item (e.g. per element area).
RAllInOneDistributionCode	Number	Residential All-In-One Rate Distribution Code (0=crisp; 1=TFN; 2=TrFN; ...).
RLabourDistributionCode	Number	Residential Labour Rate Distribution Code (0=crisp; 1=TFN; 2=TrFN; ...).
RMaterialDistributionCode	Number	Residential Material Rate Distribution Code (0=crisp; 1=TFN; 2=TrFN; ...).
REquipmentDistributionCode	Number	Residential Equipment Rate Distribution Code (0=crisp; 1=TFN; 2=TrFN; ...).
BuildingSizeCode	Number	The Building size applicabilty of the cost item (0 all sizes; ...).
BuildingHeightCode	Number	The Building height applicabilty of the cost item (0 all heights; ...).
BuildingLocationCode	Number	The Building location applicabilty of the cost item (0 all locations; ...).
UnitsCode	Number	Unit System code (0 Metric; 1 Imperial).
RAllInOnePar1	Number	Parameter (1) of the All-In-One Rate Distribution.
RAllInOnePar2	Number	Parameter (2) of the All-In-One Rate Distribution.
RAllInOnePar3	Number	Parameter (3) of the All-In-One Rate Distribution.
RAllInOnePar4	Number	Parameter (4) of the All-In-One Rate Distribution.
RLabourPar1	Number	Parameter (1) of the Labour Rate Distribution.
RLabourPar2	Number	Parameter (2) of the Labour Rate Distribution.
RLabourPar3	Number	Parameter (3) of the Labour Rate Distribution.
RLabourPar4	Number	Parameter (4) of the Labour Rate Distribution.
RMaterialPar1	Number	Parameter (1) of the Material Rate Distribution.
RMaterialPar2	Number	Parameter (2) of the Material Rate Distribution.
RMaterialPar3	Number	Parameter (3) of the Material Rate Distribution.
RMaterialPar4	Number	Parameter (4) of the Material Rate Distribution.
REquipmentPar1	Number	Parameter (1) of the Equipment Rate Distribution.
REquipmentPar2	Number	Parameter (2) of the Equipment Rate Distribution.
REquipmentPar3	Number	Parameter (3) of the Equipment Rate Distribution.
REquipmentPar4	Number	Parameter (4) of the Equipment Rate Distribution.
ItemName	Text	Name of the cost item.

Figure 4: Descriptions of fields of the cost items table

- The *AssociatedActivityCode* field stores the activity code to which the current cost item belongs. This field links the table with the option activities table.
- The *ItemNumber* is an automatically generated number.
- The *ItemName* field stores the name of the cost item.
- The *DataSourceCode* field stores the data source code of the cost item.
- The *SourceDescription* field stores the description of the data source.
- The *RateCode* field stores the data rate code of the cost item as defined in the rate codes table.

- The *BuildingSizeCode* field stores the building size code of the cost item as defined in the building size codes table.
- The *BuildingHeightCode* field stores the building size code of the cost item as defined in the building height codes table.
- The *BuildingLocationCode* field stores the building size code of the cost item as defined in the building location codes table.
- The *UnitsCode* field stores the unit system code of the cost item rate as defined in the unit codes table.
- The *DetailedComponents* field stores the level of detail of the cost item. If this field is set to 'No', only all-in-one rate is given. If it is set to 'yes', on the other hand, the labour, material and/or equipment rates are specified according to the values of the *IsLabourRates, IsMaterialRates* and *IsEquipmentRates,* respectively.
- The remaining fields define the all-in-one, labour, material and equipment rates. As shown in Figure 3, each rate is defined by a distribution defined by 5 fields: a distribution code and up to 4 parameters to define the distribution.

EDITING AND ADDING DATA

In MS Access 2000, adding data is straightforward and three ways of data entry are possible. In the first method, one can simply open the targeted table in datasheet view and start typing the new data. However, this method is not convenient especially when dealing with large amounts of data and/or with data related through two or more tables. This method has been adopted in adding data for simple auxiliary tables. In the second method, data can be entered through a query. This method has the obvious advantage of being fast and automatic. In the third method, data can be entered through a customized form that includes a selection of fields. This method has three advantages. First, it is user-friendlier. Secondly, additional information on the required data can be displayed. Thirdly, and more importantly, data for fields in two or more tables can be simultaneously entered and automatically included in these tables.

A user-friendly form has been designed for adding data to the three main tables (Figure 5). As shown, the form is well organized. Besides, event procedures written in Visual Basic® have been also written for all controls to make the form smarter, e.g.

- The finish subtypes are automatically set depending on the selected finish.
- Non-financial criteria are automatically set depending on the selected finish.
- The required parameters for uncertain variables are automatically enabled with a user-friendly 'tip text' displayed to explain the field at hand when entering data.
- For option activities, the appropriate time data and controls are automatically set.
- For activities cost items, the appropriate rate controls are automatically set according to the required level of detail.

TESTING AND VALIDATION

The developed system has been tested and validated in three phases. First, the usability of the database's interface has been tested in a laboratory environment. This required that various constituent databases operated efficiently, and in a manner allowing for data transfer between parts of the system. The resource database was rigorously tested to ensure that all data pertaining to individual materials could be stored by the system, and that the criteria and options available to users complied with current guidelines. Similarly, dummy data was inserted in the project database, to ensure that the system raised the correct ‘prompts’ for users, and to ensure that the resulting data analysis was mathematically correct.

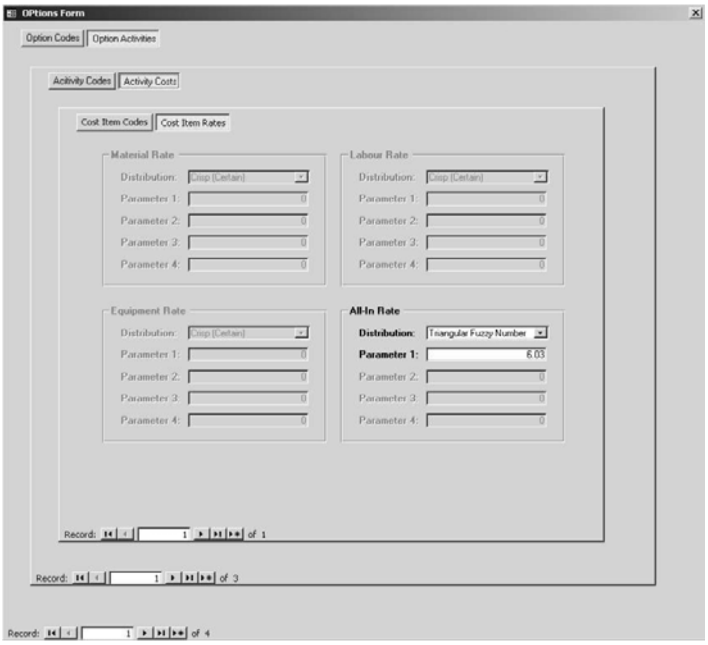

Figure 5: Data input form

The second stage of refinement, which involved presentation to a panel of experts acting as a project steering group, resulted in two key alterations to the system. The first of these involved contents of the resource database, which it was determined should be populated with generic material ‘types’ at this stage, which could potentially be overwritten or superseded by actual product data once the system came into use. Secondly, the decision was also taken to establish two case studies, each of which would contain resource and project data pertaining to two hospital spaces. The rationale for this was to provide a basis upon which participants in the third stage of testing can assess the application of the system in simulated design and maintenance situations. This will be reported in a separate paper.

CONCLUSIONS AND THE WAY FORWARD

A generic WLC resource database has been designed and implemented into MS ACCESS. The database structure was designed on the basis of an in-depth analysis of the requirements of effective WLC decision-making during the design stage within an integrated environment and the limitations of previous efforts to utilize databases to facilitate whole life costing as discussed in the first part of this report.

The database relational structure is explained and the data types and descriptions of fields of various tables are reported. Data are stored in three main tables. Besides, eleven secondary tables including the definitions of various codes are also employed. This flexible structure of the database allows extracting WLC data on four levels: the space, the activity, the cost item, and the cost component levels. In addition, a user-friendly input form was designed to facilitate editing data of the three main tables. The most unique feature of this form is that it minimizes the user input as only the required fields for a given situation are enabled. Besides, combo box controls are used, whenever possible, to further facilitate the input process.

Further research work includes developing and validating a decision support system by integrating the resource database with an extended WLC application. The development of the system and its validation is reported in detail in a separate paper.

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