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A Case For Decision Enterprise Modelling

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Abstract

With emergence of data driven decision making, data analytics and data science, regular as well as ad-hoc decision making has become important. We argue that this requires to model the decisional behaviour of an enterprise as different from its functional behaviour. We propose Decision Enterprise Modelling as a multi-model activity consisting of three models, the Decision Structure Model for modelling business decisions, a Decision logic Model for representing decision logic and a Decision Information Model for the data needed for decision making. We present an example of Decisional Enterprise Modelling for a micro-organization.

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1. Introduction

Enterprise modelling is the activity of building a model of an enterprise to gain an understanding of the enterprise and improve enterprise performance. An enterprise may be [1] the whole or part of an organization, a team of people, a work unit, an activity, or a set of business processes. It caters to the needs of Software/Information

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systems engineers, Industrial engineers, and Business Analysts. There are several definitions [1] of an enterprise model, EM. An early one [2] is that an EM is an abstract representation of the structure, processes, information, and resources of an enterprise. Thus, an EM has multiple viewpoints, each with its own model. For example, ArchiMate [3] considers an enterprise in three layers and three aspects, providing nine viewpoints of an enterprise. An EM has two basic models, (a) Function/process/activity diagrams, and (b) Data models. Several proposals [4, 5, 6, 7, 8] link business processes to the strategic purpose of the business.

Whereas an EM is activity-oriented, we propose here the notion of a Decision Enterprise Model, DEM for modelling as enterprise-during-decision-making. There are two kinds of decisions in enterprises, (a) repetitive decisions like periodic buying, discounting, and hiring decisions, and (b) ad-hoc, infrequent decisions like expanding into a new line of business. The As-Is DEM represents decisions now whereas the To-Be DEM reflects the decisions in the enterprise of the future. The To-Be model may represent new alternatives/optimization criteria to be adopted during routine business, or new decisions due to exception situations like business restructuring, mergers/acquisitions/hive-offs etc.

A DEM answers questions about an organization like (a) What decisions are being made? (b) Who are the decision makers and which decisions do they take? (c) How are decisions evaluated and selected? and (d) What data is needed to support decisions? To address these issues, we propose a multi-model DEM consisting of (a) Decision Structure Model (b) Decision Logic Model, and (c) Decision Information Model. Our DEM addresses the needs of (i) Engineers building Decision Support Systems, by specifying the decision logic and the required data (ii) Data analysts and data scientists, by identifying the needed data to be processed for producing the required analytics and verifying hypothesis, (iii) Business people looking to re-engineer the decisional enterprise, by As-Is and To-Be models.

In this paper, due to space limitations we deal with the Decision Structure Mode only. In the next section, we provide an overview of the basic notions of decisions and decision making. In section 3 we consider DEM, outline its properties and the relationship between its three models. Section 4 contains a description of the Decision Structure Model. An example of DEM is presented in section 5 and related work is considered in section 6.

2. Basic Notions of Decision Making

The term, decision [9] has two connotations, (a) it is the act of selecting from among a set of choices, and (b) it is the selected alternative itself. Eisenfuhr [10] views **decision making** as the process of making a choice from several alternatives to achieve a desired result. Accordingly, decision making corresponds to the meaning (a) above. In [11] the set of available alternatives is referred to as a choice set and the selected alternative is referred to as a decision; this is (b) above. In this paper, we will use decision making in the sense of [10] and decision as in [11].

A decision is selected to solve a decision problem that is expressed in [12] as a pair, $\langle \Omega, OP \rangle$ where Ω is the choice set, a set of alternatives from which an alternative is chosen and OP is an optimality principle that may be single criterion or multi-criteria. The probability of selecting any alternative is the same. The decision-maker sets this problem and finds its solution. The solution is the set of alternatives, Ω_{OP} , selected by the optimality principle, OP. The outcome of each alternative is computed before applying OP. Consider purchasing a product from different vendors and OP as “Minimize Cost”. Cost is computed for each vendor to decide minimality, and there may be multiple vendors with the same minimal cost. However, it has been observed that besides OP, managers consider other factors as well. These are as follows:

- Critical Success Factors, CSF [13] or key work areas in which achieving success is essential for a manager.
- Ends effectiveness [14] is a factor for estimating the impact of a decision. ‘Ends’ refers to the result achieved by a decision. Managers choose the alternative whose result is most effective.
- Means efficiency [14, 15] estimates the cost of a decision. A Means is the activity performed to achieve an End and its efficiency goes into decision selection.

- Outcome feedback [16] occurs due to the effect of our decision on the business environment. This effect changes the conditions of choice and eventually feeds back into the decision. A feedback cycle is thus formed. Therefore, the effect of a decision must be considered in making the decision.

Thus, a Manager Decision Problem, MDP, is $\langle \Omega, OP^m \rangle$ and OP^m includes manager factors in addition to OP .

There are two interesting properties of decisions, (a) it is a commitment to an action or a course of action. We shall use the term action to refer to both the action as well as the course of action and (b) the action is completely performed.

3. Defining the DEM

A DEM is a representation of a single MDP or multiple MDPs of an organization, department, division, plant, work unit, or group of people. Fig. 1 shows that DEM lies within an organizational context. This context supplies the rationale for the concepts that constitute the DEM and these concepts are analogous to motivation elements of Archimate [3]. Two kinds of motivation elements for decisions have been proposed, Goals [17] and Policy [18], respectively. Fig. 1 shows a DEM as multi-model consisting of three models namely, the Decision Structure Model, DSM; Data Information Model, DIM and the Decision Logic Model, DLM. Once decisions are determined from the context, the DSM is built and it supplies inputs for building the other two as shown by the arrows emanating from the DSM in Fig. 1. The information identified in DSM is elaborated and modelled in DIM whereas OP^m identified in DSM, is used to develop the logic for computing Ω_{OP^m} . This logic is modelled in DLM. DIM and DLM exchange information, the former supplies input for decision logic whereas data produced in DLM is stored in DIM.

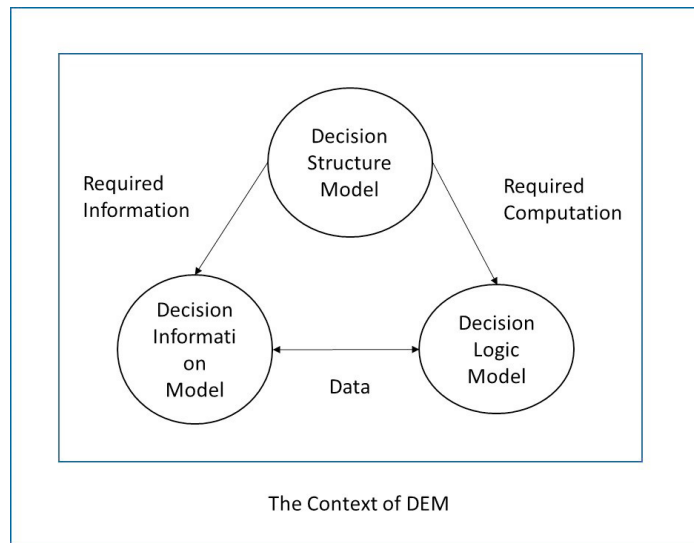


Fig. 1: The DEM in its Context.

The **DSM** as its name implies models the structure of the MDP. It represents the typology of alternatives, the action associated with each alternative, and the outcome that each alternative produces to enable determining Ω_{OP^m} . Further, it considers the nature of decision-makers and identifies the decisions for which they are responsible. Lastly, the information of interest in the MDP is identified. This may be internally generated information in the business or that coming from the external world like taxation data.

The **DLM** provides the computation model using which outcomes of alternatives defined in the DSM are determined. These models may be decision trees, decision tables etc. It is possible that a computation procedure is well defined as in structured problems or it may be partially defined requiring human intervention as in semi-structured problems. If the problem is completely unstructured then the DLM for a decision may be empty.

The **DIM** models the information required for the MDP. This information may be about the current state of the enterprise; data about alternatives like for each supplier, Supplier Name, Supplier Address, and Supplier turnover; arguments needed to compute the outcome like Product list price, Tax, Shipping for computing the outcome, Cost; and data about managerial factors.

4. The Decision Structure Model

The DSM is presented in Fig. 2 in UML notation. There are **three kinds of alternatives**. An **atomic** alternative cannot be decomposed into simpler alternatives. For example, when selecting a flight, we have two alternatives, Cheap airline or Regular airline. These have no components. A **complex** alternative is composed from other alternatives that are “is part of” the complex alternative. The complex alternative is selected only after all its components are selected. For example, consider an airline, A that offers options for ordering various kinds of food, and selecting seats when booking. The alternative, Select A requires that these two component alternatives be selected for A to be considered selected. Lastly, it is possible for an alternative to itself be a **choice set** that contains at least two sub-alternatives. For example, consider the choice set {Travel by air, Travel by train} for selecting a mode of travel. Travel by air is itself a choice set, {Cheap airline, Regular airline}.

An alternative participates in several relationships as shown. The first is the reflexive “**Depends on**” relationship that says that an alternative needs the outcome of the alternative upon which it is dependent. That is, alternative A₁ is dependent upon alternative A₂ if the outcome of A₂ is accessed by A₂. The figure shows that an alternative is a “**Commitment to**” an action. As discussed in section 2, this action may be an individual action or a course of action. The relationship, “**STKH**” identifies the decision makers responsible for decision-making. It associates decision makers with the alternatives available to them.

There are different kinds of decision-makers. **Individual** decision-makers are completely responsible for the decisions they make. **Multiple** decision makers each has a stake in making the correct decision. There is a common, overarching decision that is to be made and each decision maker makes a decision that contributes to the global decision, as, for example, during product design. **Group** decision makers work together to take a decision. They form a committee and each member has equal say in decision making, as, for example, reviewers of conference papers. **Team** decision makers work as a team with a clearly designated team leader. This leader is an individual who is the final authority. These four types are not shown in the figure so as not to clutter up the graphics.

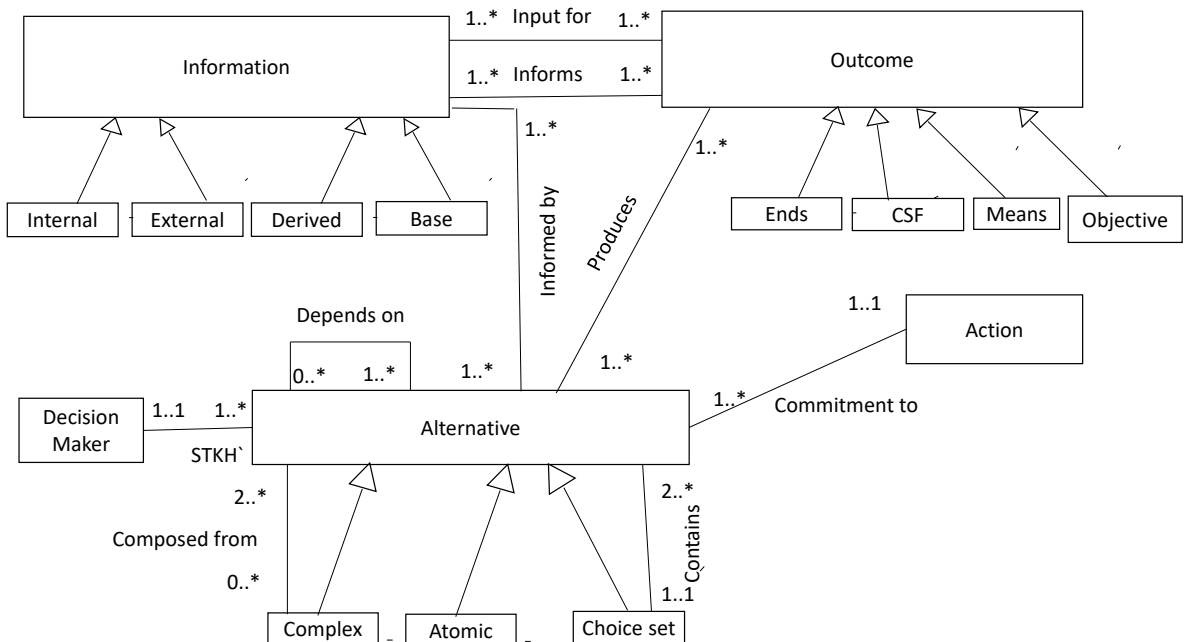


Fig. 2: The Decision Structure Model.

An alternative also participates in relationships with Information and Outcome. Information represents data that is generated either internally in the business or is obtained from external sources. These are shown as Internal and External in the figure. The figure shows that alternatives are “**Informed by**” Information. This makes available data about alternatives, for example for each vendor, Vendor name, address, etc. The different kinds of Internal/External information are not shown in the figure for graphical reasons and are as follows. **Internal sources are** (a) transaction Data, (b) information for assessment of Ends effectiveness or ENDSI, Ends Information, (c) information for assessment of Means efficiency or MEANSI, Means Information, (d) information for CSF assessment or CSFI, (e) information for outcome computation, and (f) information about alternatives. **External sources** are data from regulatory bodies, rules and laws, data from outcome feedback etc.

An alternative produces one or more outcomes as shown in Fig. 2 by the relationship, “**Produces**”. There are four kinds of outcomes as shown. Objective is the outcome produced by computing the function of OP like cost in Minimize cost. The outcomes Ends, Means, and CSF are all for manager factors.

Lastly, the figure shows that Information may be Derived or Base. The former is computed from other derived or base information. Information is needed as “**input for**” computing outcomes. It is also needed for informing outcomes. This happens when manager factors are unstructured in nature, cannot participate in the computation of outcomes, but need to be considered. For example, a user survey for Ends effectiveness may give the text value, “good” and needs to be factored in.

5. A Case Study

We used DEM as a basis for developing a data warehouse for a small enterprise in order to find empirical support for our ideas. Selection of the enterprise was done by issuing a call to about 125 students of Master of Technology who had completed a one-semester course on data warehousing. The conditions for selection were that students should have obtained at least a B grade and should have access to a company that would be treated as the enterprise for the case. Agreement of the company was essential for selection. One group of two students responded to the call. They developed a DEM for their micro enterprise and then used DIM for delivering a data warehouse. The enterprise manufactures decorative components like trims, rings, and canopies for fans. The main material used are plastic grains, chemicals and paints for coating and baking plastic components. The company has about 20 employees and three family members manage the company. Each family member is responsible for specific aspects of the business, one for dealing with clients as well as production in the moulding unit, the second for accounts, HR and quality control, and the third for the coating unit. Because of reasons of space, we present the DSM for the first aspect only and, additionally, omit the later steps of building a data warehouse. Details can be found in [19].

Since there was no formal documentation, the independent method of data collection [20] could not be used. Further, decision makers were not familiar with concepts of decision-making and this ruled out the structured questionnaire approach. The unstructured interview approach was therefore adopted during which data collection and explanation of what was needed went hand in hand. Data collection started from the stakeholder who was available the earliest. Observer triangulation was done and each student kept a record of the interview which was then compared with that of the other to reach a common understanding or to seek clarifications. Data collection was targeted to instantiation of the three models of DEM. Students reported back once a week for data logging, identifying any further clarifications that might be needed, modelling DSM and laying down the work plan for the next week. The DEM was created using drag-and-drop features of our tool that implemented DSM, DIM, and DLM.

The DSM is presented here as several tables. Since we have picked up the moulding unit for presentation, the only decision maker is the first family member. Thus, the STKH relationship says that all alternatives pertain to this decision maker only. The choice sets and alternatives are shown in Table I. There are a total of 5 choice sets and 11 alternatives.

Table 1. Choice Sets and their Alternatives.

Name of Choice Set	Set of Alternatives
Process Order	{Accept order, Reject Order}
Maintain Contact	{Maintain Client Contact, Maintain Customer Contact}
Ensure Supply	{Periodic Restock, Stock rupture Restock}
Reschedule Production	{Add order, Remove order}
Handle Waste	{Sell as scrap, Recycle, Sell as seconds}

The type of each alternative is in the second column of Table 2. Only 6 of the 11 alternatives are presented to provide a flavour. The third column shows the alternative dependent on the alternative in the first column.

Table 2. Types of Alternatives and their Dependencies.

Alternative	Type of Alternative	Dependent alternative
Accept Order	Choice Set (Negotiate Price, Negotiate Delivery, Determine Quantity)	Maintain Client Contact
Reject Order	Atomic	Maintain Customer Contact
Maintain Client Contact	Atomic	Nil
Maintain Customer Contact	Atomic	Nil
Periodic Restock	Choice Set (Select Vendor, Fix quantity, Fix price)	Nil

The outcomes of our alternatives are shown in Table 3. Objectives are shown for each alternative in the second column and are self-explanatory. There are four CSFs of the manager, namely, ensure Healthy Order Book, maintaining good client and customer relations respectively, and ensuring adequate inventory of material. Ends effectiveness of accepting orders is assessed by the number of satisfied customers; rejection is effective if the reasons for rejection are specified; maintaining client contact if there are repeat orders; maintaining customer contact if past customers become clients and restocking, if demand is satisfied. Similarly, efficiency of means for order acceptance is ensured by having rapid response times.

Table 3. Alternatives and Outcomes

Alternative	Objective	CSF	Ends Effectiveness	Means Efficiency
Accept Order	Maximize Order quantity & Maximize Order value	Healthy Order Book	Satisfied Customer	Low lead time
Reject Order	Minimize Rejection	Healthy Order Book	Reasoned rejection	Low Lead time
Maintain Client Contact	Keep Client Data	Good client relations	Repeat Orders	NIL
Maintain Customer Contact	Keep Customer Data	Good customer relations	Converted Customers into Clients	NIL
Periodic Restock	Minimize Inventory	Adequate material	Satisfied Demand	Timely restocking

To give a flavour of the needed information, Table 4 gives CSFI needed as input for estimating its CSF.

Table 4. Alternatives and their actions

CSF	CSFI
Healthy Order Book	product_id, quantity, value, order_date, Order_delivery_date
Good Client Relations	Client_id, Contact_date, Contacter_id, Client_requirement
Good Customer Relations	Cust_id, Contact_date, Contacter_id, Material_communicated
Adequate Material	Product_id, quantity_on-hand, value_on-hand, date

The action associated with alternatives and the transaction data generated from these actions are presented in

Table 5.

Table 5. Alternatives and their actions.

Alternative	Action	Transaction Data
Accept Order	Put in order book	Order-id, client_id, product_id, quantity, value, date
Reject Order	Put in reject list	Order_id, Cust_id, product_id, product_desc, value
Maintain Client Contact	Update Client Data	Client_id, Client_name, Client_address, Client_phone
Maintain Customer Contact	Update Customer list	Cust_id, Cust_name, Cust_address, Cust_phone
Periodic Restock	Order Material	PO_no, PO_date, PO_vendor_id, PO_material_id, PO_quantity, PO_value

The study threw up some interesting points. **First**, despite the decision-making role, the manager of the moulding unit thought in terms of actions. Initially, we had to move from actions to alternatives/decisions before the manager got used to the notion of an alternative/decision. **Second**, definitions of the scope of decisions were confused and clarified during interactions. For example, the alternative *Accept_order* meant updating of the order book for one manager and scheduling coating for another. This affected the decision responsibility structure of the company and led to better clarity of the role of different managers. **Third**, manager factors were considered informally but the DEM explicitly focused on these. The decision-maker appreciated the value of this when ENDSI, MEANSI, CSFI were determined. **Fourth**, outcome feedback did not play any significant role in the DEM.

6. Related Topics

Consider DEM and DSS applications. Interest in DSS is in supporting individual decisional problems, $\langle \Omega, OP \rangle$ and not in $\langle \Omega, OP^m \rangle$. Further, the effort is to provide support in decision-making but not on modelling the decisional enterprise. For DEM, decision support is a consequence of the modelling activity. Similarly, the Decision Model and Notation. DMN, a standard of OMG [9] is concerned with individual applications. Whereas it provides a notation, DMN does not consider the issue of decision enterprise modelling. DMN is useful for modelling, in its Decision Requirements Diagram, requirements of the decision logic and associated knowledge sources. When compared to DEM, it does not focus on DSM and DIM but only on the DLM.

In the area of Enterprise Modelling, ArchiMate provides features that motivate the design of an enterprise. These motivation elements in ArchiMate represent [3] “the context of or reason behind the architecture of an enterprise”. There is some common terminology in ArchiMate and Decision Enterprise Modelling but the meanings are considerably different. We consider two terms used in ArchiMate to illustrate this. The first is the notion of a stakeholder, defined in ArchiMate as “A stakeholder represents the role of an individual, team, or organization (or classes thereof) that represents their interests in the effects of the architecture.” This definition motivates the architecture of an operational enterprise and stakeholders are actors whose operational interests are represented in the architecture. In DEM, a similar definition could hold but with the caveat that it is the decision-making interests of stakeholders that need to be represented in the architecture. The **second term** used in ArchiMate is “outcome” and it is specified that “An outcome represents an end result.” Outcomes are further described as high level business-oriented results produced by the core elements of the enterprise. Again, these results are not in the sense of decision making where each alternative produces its own outcomes that are then compared/evaluated to select the most appropriate alternative. The notion of an outcome of an activity is thus considerably different from that of an outcome of an alternative.

Data Driven Decision Making, DDDM has put the spotlight on data-as-an asset for supporting business decisions. Determination of the right data sets for the right decisions is crucial for DDDM. Data may be collected [21] with no specific purpose in mind, or may have been collected for a business problem that is not the one at hand. Thus, there is little assurance that the data is relevant to the decision currently being made. DEM facilitates a close match between decisions and their data by linking decision structure, logic and information together. There are three aspects of a DEM that we wish to highlight:

1. DEM can model any kind of decision, operational or strategic; structured, semi-structured, or ill structured. It can also model decisions [21] that need ‘discovered’ data as well as repetitive decisions for which data is already available.
2. The relationships, Informed by, informs, and input for, identify data that is worth collecting and articulates the utility of the collected data. Thus, it minimizes expenditure on resources for hosting data that shall not be used. Consequently, it also minimizes the effort of searching irrelevant data sets.
3. Decision maker identification helps in determining how decisions are taken. Thus, a decision maker can be an individual, a team leader, a committee that votes or a committee that decides by consensus. Information Technology support for DEM can support this by providing features for voting or recording consensus in the decision logic.

7. Conclusion

DEM is a model for representing enterprise decisions. It models, not just the decision problem, $\langle \Omega, OP \rangle$ but the enhanced managerial decision problem that also includes manager factors besides the standard optimality condition. A DEM consists of three models, namely, Decision Structure Model, Decision Information Model and Decision Logic Model. We have described the first in this paper and outlined the role played by the other two. Empirical support for our ideas is provided by the case of the manufacturing company for which we built a data warehouse that started out with a DEM for the company. The DEM was then converted into a star schema.

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