Decision Support System Interface for Flexible Task Allocation Using Mobile Phone Terminals

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Executive Summary

Small and medium size service companies which serve customers promptly at different locations and provide different kind home services, maintenance and repair, mansion keep-up, and alike, can take advantage mobile phone connection to decision support system (DSS). A major factor is that these companies do not have dedicated call centers but the manager is field worker and assigns tasks during customer call using mobile phone as user interface to decision support system (back-end database server) that has relevant information about employees such as their location, their special skills, the tools they have with them etc. **Task allocation** should be made so that company's resources are utilized optimally. DSS provides suggestion for optimal solution based on the facts which the field manager has given as input during the customer call.

This study compares ten possible user interfaces for decision situation which take into account the fact there should be good balance between human flexibility given to the field manager and DSS's complexity. This study suggests that so called **Schedule Model** should be used in task allocation. It shows employees schedules and creates view which resembles project flow view used in project planning software, though minimally. Additionally so called **Traditional Decision Making with Attributes and Weights (TDM) –model** is suggested to interface with the DSS foundations in order to change foundations of the decision making so that it models ever changing business environment that these kind of service companies face year around.

Abstract

Decision making with a mobile telephone is area of great business expectation but still with little scientific research. In this study we have search different kinds of methods for solving the dilemma with the balance between an easy-to-use, intuitive user interface fitted on a mobile screen and a thorough decision support system (DSS). The study introduces number of approaches for the DSS and makes a comparison between them and a proposition for the best solution in general taking into consideration the dependency of circumstances to these kinds of propositions. Also we have figured out future research directions for this research area.

This study is a project work for the Seminar Case Studies in Operations Research and it is done with co-operation with Nokia Research Center.

Keywords: Mobile, Decision Support System, Task allocation, Graphical Decision Making

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1. Introduction

This is a project report written in the course Mat-2.177 Project seminar in operations research. The aim of the course is to use obtained knowledge in the field to solve a problem from the real world. Our team was assigned a project from Nokia Research Center in Helsinki and our task was defined by the client organization as "Decision Support System Interface for Flexible Task Allocation Using Mobile Phone Terminals". The main idea was to find the best way to support on-line decision making using only a small mobile terminal screen for displaying information. The project was started in January 2006 and the dead-line for the report was at the end of April 2006. During this period, the team meat with the client, with the responsible professor, gathered several times for planning purposes, obtained material for existing literature, and invented different way for solving the problem. We used a web-site for internal information, in which all documents and the time-line was stored. There was a project manager responsible for practical issues, such as contacting the client and the professor, organizing meetings, and administrating the web-page. Each member of the team was responsible for an area of the project, but all members took part in all aspects of the project. The scope of the project changed somewhat in the middle, but as the change mainly broadened the scope before we had digged too deep into the project, no extra work had to be done.

Problem description

The problem given by the customer was the following:

> ”*Take a small or medium sized company with on-site customer service and workers constantly on the field. If the company doesn't have a call center, somebody – most likely a manager on the field – has to take customer calls and make decisions regarding the allocation of workers. The customer will have to get information about the estimated arrival time of the service. The system supporting the decision maker may be completely automatic or preferably interactive and allowing the decision maker to change decisions after the initial suggestion of the system.* ”

The following tasks were identified:

- What different ways are there to approach the problem? —Even though the most obvious approach from the field of operations analysis is the weighted criteria method, we were given a task to find non-obvious ways to support decision making.
- What are the pros and cons of these approaches? —The group was to develop a way to evaluate the different solutions, e.g. by interviewing experts, simulating situations, or using common sense. This evaluation should result in some approaches being discarded whereas some are kept for further studies. Also, during the evaluation, the approaches themselves should be further developed, so that they better answer real world problems. Finally, one single solution should be chosen from the portfolio.
- Which approach do you recommend? —After having identified the best way to approach the problem, the chosen solution will be developed as far as possible and then documented for customer purposes. Also the earlier evaluations will be documented as material for further studies.

Another task that is incorporated in the problem description was to find literature in the fields of interest. This research was carried out by using databases such as ISI Web of Science, Google Scholar, and others. Non-electronic resources were not used and there may thus be openings in the literature study.

2. Literature Study

The project begun with literature study focused on decision support systems, visual decision making, scheduling, and task allocation. We found a lot of articles about the scheduling and task allocation containing many effective algorithms and methods. We also found some studies considering the visual decision making but most of them were quite common level. However we did not found any remarkable articles or studies about mobile decision support systems.

2.1. About Decision Making

Even though the logic behind an allocation of workforce may or may not be created automatically by the computer system, a decision maker has to at least accept the allocation, or take actions from adjustments to complete allocation designs. The decision maker has the responsibility of his actions.

The decision may be rational and based on complete data, rational and based on incomplete data, or non-rational.

Rational decisions based on complete data

A decision making problem focuses on optimizing the utility of the decision maker. If the utility can be expressed mathematically, we can use algorithms to solve an optimal solution. With a single criteria or a one-dimensional utility function, the case is reduced to a simple optimization problem, in which the criteria is minimized or maximized. Typically the criteria is time to customer or total revenues. This problem and its solutions are considered widely in [Taha 2002].

If there are several criteria and thus a multidimensional utility function, the values of the criteria have to be commensurable and weighted in order to form the utility function. Often, the criteria are given weights from 0 to 1 or 0 % to 100 % so that the sum of the weights is 1, so that the problem yields:

$$\max U(x) = \max w_1 U_1(x_1) + w_2 U_2(x_2) + \ldots + w_n U_n(x_n)$$
$$0 \le w_i \le 1, \forall i = 1..n$$
$$\sum_{i=1..n} w_i = 1$$

where U(x) is the utility function and x_i is a criteria.

There are several methods of weighting the criteria once their relative or absolute importance can be expressed, such as AHP [Saaty 1980] – other methods such as the pricing-out method, the swing-weighting approach and the lottery-approach are presented in [Clemen 1995, pp 547-550]. These weighting methods can be used if the decision maker has the ability to express his preferences in form of absolute or relative values.

Rational decisions based on incomplete data

If the data needed for perfect decision making is not completely available or there is uncertainty involved in the data, the decisions have to be made without certainty of optimal results. The decision maker has the choice between finding ways to attain the missing data, using statistical information to estimate the missing data, or to remove the data in question from the decision making structure. Attaining the data induces new costs and becomes finally too expensive to be considered, so at least in some cases decisions have to be made based on probabilities or estimations.

Statistical distributions may be used, if the data is such that statistical data can be gathered. There are however many situations, which are so unique by nature that the decision maker will have to estimate the missing data or at least its range himself. According to [Clemen 1995] there are different heuristics a person can make probability assessments with. These may easily result in a bias, due to the following reasons:

a) ***Representativeness***
A classification is made by comparing the information known about a thing with the stereotypical member of the category ("An old woman living in a good neighborhood – must be rich").

b) ***Availability***
Judging the probability that an event will occur according to the easy with which we can retrieve similar events from memory ("It takes me ten minutes to drive a similar distance, so I'll guess it most likely will take Bob ten minutes this time as well").

c) ***Anchoring and adjusting***
One chooses an initial anchor and only adjusts this assessment later. ("Last week we had 20 cases each day, this week it will then be 22").

d) ***Motivational bias***
Incentives may lead to forecasts that do not entirely reflect true beliefs. ("John will have the job done in 15 minutes and that will give him time to take the next job, so that I don't have to go there myself").

Non-rational decisions

Even if the decision maker has all the data he needs for making a rational decision, he may choose not to do so, and make an intuitive decision which contradicts suggestions given by a rational methodology. It may even be necessary for the decision maker to have a veto-right towards any suggestions made by a computerized system. In situations with a tight timescale, the decision maker will have to use intuition instead of even making a full scale assessment of the situation. In [Khatri, Ng 2000] the authors study the use of intuition in different environments, where perfect data is not available. With intuition they mean reliance on experience, reliance of judgement, and gut feeling. They conclude that intuition should be used cautiously in a stable environment and more often in an unstable one. The study made by [Eisenhard 1989] suggests in fact that fast decision makers use more information and develop more alternatives than slow ones.

2.2. Scheduling and Task Allocation

Task allocation has been quite classical target of applications for linear programming (LP), integer programming and network optimization. Also shift scheduling problems have been solved with same kind of approach since 1954 when G. B. Dantzig (1954) formulated shift scheduling problem as an integer programming problem.

Despite the fact that task allocation and scheduling problems are quite easy to formulate as network optimization problems and furthermore LP-problems or integer programming problems, those problems have been found to become too large to solve optimally in many practical situations. Quite often these problems become NP-hard problems and there is need for different kind of heuristics and meta-heuristics to solve them. Exact optimal solution is also rarely needed in practical applications and different kind of heuristic methods and approximations ends sufficient solution.

The DSS considered at this project is focused on small companies and it consists of quite few agents. Because of that the graph used in optimization problem remains reasonably small, which enable optimal solving. In some cases, when many criteria are included the decision making problem, there might be need for heuristics and approximations. However task allocation and scheduling problems in this project are so simple that we are able to find efficient method to solve task allocation and scheduling problems in any case.

We have done some literature study about the appropriate task allocation and scheduling methods for this project. In our DSS an important point is that the scheduling has to be real-time and dynamic. There has been very little academic research on real-time scheduling, but scheduling in general has been studied quite a lot in recent decades. We adopt the statistic scheduling method for the dynamic situation in different ways at this project.

2.3. Pure Optimizing Methods

The classic LP-formulation for task allocation is:

$$
\begin{aligned}
\max \quad & \sum_{(i,j)\in A} a_{ij} x_{ij} \\
st. \quad & \sum_{\{j|(i,j)\in A\}} x_{ij} = 1, \qquad \forall i = 1,\ldots,n, \\
& \sum_{\{i|(i,j)\in A\}} x_{ij} = 1, \qquad \forall j = 1,\ldots,n, \\
& 0 \le x_{ij} \le 1, \qquad \forall (i,j) \in A,
\end{aligned}
$$

where a_{ij} is cost for assigning worker i to task j and x_{ij} equals to 1 if worker i is assigned to task j and otherwise x_{ij} equals to 0 (Bertsekas, 1998). Most optimization methods for task allocation and scheduling are based on that formulation. In scheduling workers are assigned to some tasks for a particular time, which are not identical. Time based constraints have to be added to the problem, which makes it much more complicated compared to task allocation problem.

One approach for formulation of scheduling problem is to make scheduling as shifts. This model is suitable for service sector where work has been done in shifts. We can also use this kind of idea as a base for the scheduling approaches in our project. Dantzig formulated a shift scheduling problem as a integer programming problem in 1954. The formulation was:

$$\begin{aligned} \min \quad & \sum_{k \in K} c_k X_k \\ st. \quad & \sum_{k \in K} a_{kt} X_k \geq b_t, \qquad \forall t \in T \\ & X_k \geq 0, \quad X_k \in \mathrm{Z}, \quad k \in K \end{aligned}$$

where X_k is an integer variable defined as the number of employees assigned to shift k, T is the set of planning periods covered by the shift schedule, K is the set of all shifts, b_t the number of employees needed in period t to achieve the desired service level, c_k is the cost of assigning an employees to shift k and a_{kt} is equal to one if period t is a work period for shift k and zero otherwise (Aykin 1998, p. 383).

Bechtold and Jacobs (1990) developed an advanced model which is based on Dantzig's model, but break placements are modeled implicitly. Their method is based for following assumptions: (1) the system operates less than 24 ours daily, (2) planning periods are equal in length, (3) each shift is given a single break, (4) the break duration is identical for all shifts, (5) the break duration is one or more periods, (6) each shift has a single break window associated with its time span, (7) breaks should start and end during the shifts, (8) no extraordinary break window overlap exists, and (9) no understanding is allowed (Aykin 1998, p. 383). Because of this assumptions this method is limited only certain types of problems.

Aykin (1996) has presented another formulation which is based on Dantzig's formulation, but break placements are modeled implicitly. Bechtold and Jacobs (1990) uses break variables associated with each planning period and matches breaks with the shifts implicitly whereas Aykin (1996) defines separate break variables for each shift. Aykin method has also founded little bit efficient and capable for more cases than Bechtold and Jacobs (1990) (Aykin 1998, s.390-396).

It is possible to use scheduling and task allocation method based pure optimization in our DSS, but much more convenient method for our dynamic decision making situation is a meta-heuristic which is based on these optimization methods.

2.4. Heuristics

For wider problems there are several heuristic methods for task allocation and scheduling problems. Hur et al. (2004) have found two capable heuristics for dynamic real-time situations: Sequential Mixed Integer Programming (MIP) with Loose Bounds (LB) and Build-Drop-Assign (BDA) with Greedy Search (GS). The LB approach adopts a sequential approach to the preemptive goal programming models, and accelerates the LP based branch and bound process by relaxing the optimality criteria. The BDA heuristics starts from the initial work schedule, and modifies it via heuristic search rules. Both of these two methods have also two variations: efficiency first and convenience first. (Hur et al. 2004, p. 328-329)

Tormos et al. (2003) has developed a robust heuristic method for the resource-constrained project scheduling problem. This method maintains its effectiveness regardless of the sizes of the instances. The method is named Sampling Selective Backward-Forward technique and it is combination of a random sampling procedure and backward-forward method applied in a selective way (Tormos et al. 2003, p. 1075). Thormos et al. (2003, p. 1074) also propose Parameterized Regret-Based Biased Random Sampling for the most powerful random sampling method. Multi-pass backward-forward heuristic scheduling approach was presented by Li et al. (1992).

Hapke et al. (1996) has developed meta-heuristic method for multiple-criteria scheduling problems that is based on idea of multiple-criteria programming. The meta-heuristic consist of two stages. In the first stage a large sample of approximately non-dominated schedules is generated by the Pareto Simulated Annealing (PSA). In the second stage an interactive search over the sample is organized by the Light Beam Search (LBS). In interactive search the DM is able to give remarkable contribution for the scheduling method. (Hapke et al. 1996, p. 317-319)

Hur et al. (2004b) have made a case study which investigates managers' decision in real-time schedule adjustments at two McDonald's fast food restaurants. They compare the decisions of senior and junior managers with each other and influence of part-time and full-time workers mix to the scheduling and profit. Results of the case study (Hur et al. 2004b) are then compared to real-time scheduling decisions made by computer based heuristics (Hur et al. 2004a). The study indicates that the computer based heuristics achieve higher profit than experienced managers, but the demand has to be forecasted quite accurately that work scheduling adjustments would be beneficial at all (Hur et al. 2004a). These results supports the assumption that DSS can really improve task allocation and scheduling at service sector, but it is also important that skilled DM manage the decision making process.

If problem can be formulated so that scheduling is made in a shifts, the problem become much simple. Corominas et al. (2004) have developed a scheduling method for these kinds of situations. They use an approach that solves a sequence of assignment problems. They had also added a rotational point of view to their scheduling method, which means that a number of periods will have to be passing before the worker can perform the same type of task again. (Corominas et al. 2004)

Agent-based approach may also be useful in workflow allocation. The idea in agent-based approach is that agents are autonomous entities with abilities to solve problems independently and agents have some kind of hierarchical structure. Agents are connected to each other according the hierarchical structure. It is possible to divide task allocation problem to smaller entities with agent-based thinking. For example in three level hierarchy this can be done defining tasks to one agent level, workers to second agent level and roles to third agent level. Role level classifies attributes of the workers and tasks and each role can be connected to one worker and one task. Roles are also responsible that this connection are done optimistic manner. (Gou et al. 2000)

Gupta (2002) has studied different kind of paradigms in a scheduling research of the twentieth century point of view. He states that even if ability to handle more complexity is increased and scheduling paradigms are expanded to include more complexity, this does not result in more or better solution approaches to solve the scheduling problems. He states that no real learning mechanism have been found to effectively solve unknown scheduling problems and at least today computer can not tell us the good solution for the scheduling problem without identifying the situation exactly.

Gupta (2002) has developed an iterative scheduling method in which it is possible to use effective interaction of DSS and DM. The idea in this iterative scheduling method with DSS is that DM first solves the problem giving the information of aggregate level for the DSS. According the responses he iterates the solution with DSS and makes decision when the specified convergence criteria are satisfied.

2.5. Applied Approaches

Practical application, in which scheduling and task allocation methods are used in DSS, differs so much from each other that basic methods may need a lot of adaptation. We studied some articles concerning task allocation and scheduling methods in adaptation point of view. These articles concerned the most important points which have to taken into account in developing new approaches.

2.6. Decision Making with Visual Support

In this part of the literature survey we are interested in the following topics: decision making under uncertainty, decision making in a time-constrained situation, non-rational decision making, and visual support for decision making. We originally wanted to explore the use of a small-sized window as a decision support interface, but the only study in this field we could find was [Marsden et al 2002].

The use of rational decision support systems is widely presented in decision support literature (see for example [Clemen 1995]) and we do therefore not discuss this subject here. What has been less investigated is the use of graphical or visual mechanisms to support decision makers. [Bielza and Shenoy 1999] touch the subject of representing decision support problems graphically, but do not go into the data representation problematic. [Marsden et al 2002] start with the same considerations as we do regarding the presentation of decision support data through a communication device and go on to develop a graphical "language" which can be more easily used than a text-based system when having a limited window. [Bieber 1995] calls for the use of hypermedia functionality in decision support systems. [Goutis 1995] uses a heuristics of directional graphs to solve decision support problems, but again the presentation of data is not an issue in the study.

[Li et al 2001] conclude that information visualization can assist decision makers in "gaining insights into the quantitative data so that eventually better decisions can be reached".

Technique	Value	Location	Data extent	Visualization extent	Axes mapping
Material prop	Scalar	3D	Discrete	Surface	Experiential
Texture mapping	Scalar	3D	Discrete	Surface, volume	Experiential
Spherical	Scalar	3D	Discrete	Point	Experiential
Affine transform	Scalar	3D	Discrete	Surface	Experiential
Magnitude/frequency	Scalar	3D	Discrete	Surface and animation	Experiential
Left/right	Scalar	3D	Discrete	Surface	Experiential
Bump mapping	Multivariate	2D and time	Discrete	Surface	Experiential
Snow angels	Vector	2D and time	Discrete	Surface	Experiential
Oscillation	Multivariate	2D and time	Discrete	Point, curve, animation	Experiential
Uncertainty glyph	Vector	1D or 2D	Continuous	Point	Experiential
Fat surfaces	Scalar	2D or 3D	Continuous	Surface, volume	Experiential
Iterated function	Systems	Multivariate, 1-3D	Discrete	Continuous	Experiential
Displacement	Scalar	2D or 3D	Continuous	Surface	Experiential
Instrument	Scalar	1D	Discrete	Point	Abstract
Subliminal	Nominal	2D or 3D	Discrete	Surface	Experiential
Ellipsoidal	Multivariate	3D and time	Continuous	Point	Experiential
Ribbons	Multivariate	3D and time	Continuous	Surface	Experiential
Batons	Multivariate	3D and time	Continuous	Point, curve, animation	Experiential
Ranking	Multivariate	3D and time	Continuous	Curve and animation	Experiential
Duration	Scalar	1D or time	Discrete	Curve or animation	Experiential

Table 1 New uncertainty visualization methods (from [Pang et al 1997])

[Pang et al 1997] present and classify new ways to visualize uncertainty. These are mostly for presenting other types of data than is used in our study, but some ideas could be extracted from this. They also present the idea of sonificating data as well as animating it.

Human factors has several articles on displaying uncertainty in data, but we didn't have access to the publication. [Aminilari 2000] could be an interesting dissertation to explore, had we access to it.

2.7. Conclusions

Literature directly relevant to our study was not found, but some references mentioned may include more relevant studies. We found some support for the approaches we suggest in later chapters, but some remain tentative in this context. Intuition as a decision making method, appears in publications from several different fields and seems to be especially relevant in unstable environments. The use of visualization to present uncertain data has a solid base in literature. We didn't find many relevant studies on small-screen decision support interfaces, so it seems our study has some novelty value in the field.

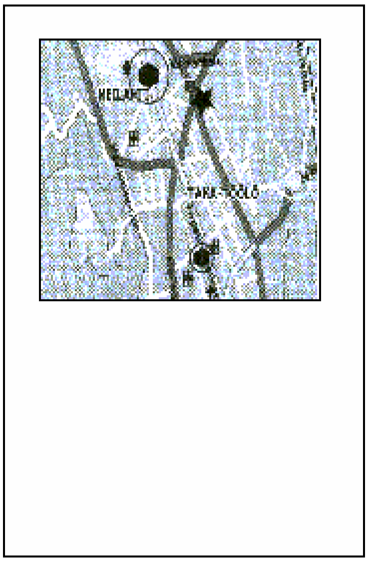
3. Methods

In this section we present different proposals for mobile user interfaces describing first their general description from the users point of view and then describe theoretical features.

3.1. Map Visualization

Description

Map visualization is a totally visual approach founding its roots on a normal and common map-view –principle. The bases are that the view is in fact a geographical map, where target and all the employees are presented as different visual marks. The marks are represents certain kind of attribute or criteria of the quality of that target or employee.



Picture 1 Map Visualization

First of all on screen is the map so that the target is either on the center of the screen or otherwise so located that other marks are equally shown on the screen. The employees are shown on the map according to their location at that time. Also the screen is shown some kind of scale measure, so that distances can be proportioned.

Target has a mark that represents some important criteria of that task. The employees are shown on the screen with different kinds of color and size marks. The color indicates specific criteria of quality concerning such that task, such as available tools, know-how, timetable etc. Size marks would represent the optimum solution on that task, for example the largest mark is the systems proposal.

At first DM will present the task answering some vital questions, such as the location of the task, description of the work needed to be done, urgency of the work etc. After that the system will load the map view and the employees are shown also, with calculated information related the task. DM will then choose the optimum solution proposed by the system or some other worked from the screen. After that the decision is send to the chosen worker who then accepts or denies.

Theoretical Definition

This approach will show the problem in a visual way, so that the DM has the most intuitive touch selection the best solution. Also here the DM will at first has to describe the task with simple and precise criteria. Then the system will draw the target and the employee on the screen on a map.

Marks are shown according there location on the map, so the distance criteria is shown easily to the DM. The marks on the employee are drawn so that the colors will represent some vital criteria that are defined on the configuration. The employees are drawn the size of the mark related to the optimum solution, so that the worst worker has the smallest mark and the best the largest one.

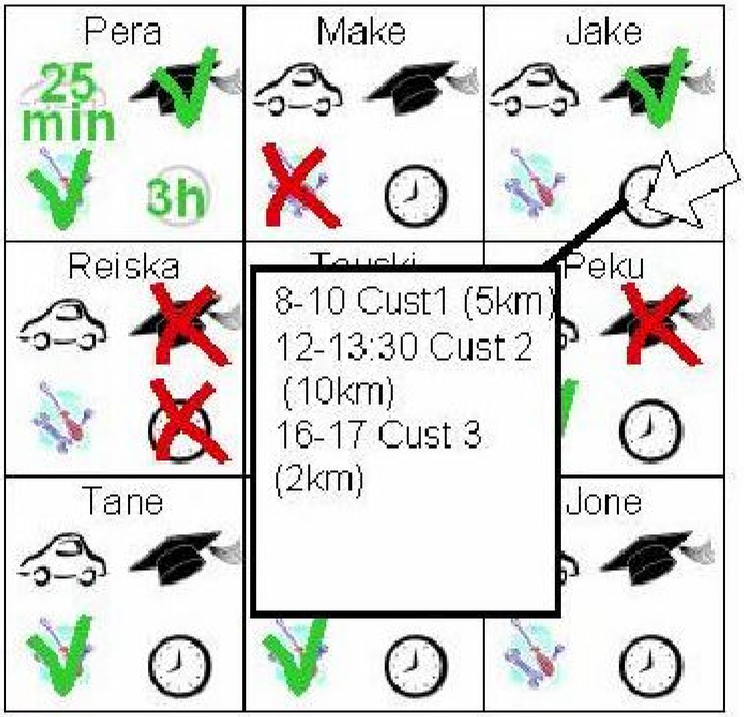
The optimum solution is calculated based on the description of the task and criteria and there weighting coefficient defined on the configuration to match the industry on question.

The map is scaled so that the target should be on the middle (unless the employees are all located to same corner) and that all the employees should be shown.

3.2. Table View

Definition

The table view approach uses a small amount of relevant data to produce a solution for the decision maker. The data can be time to customer, knowledge in the problem field, scheduled free time, needed tools etc. (see picture below). This data is then represented on the screen of the device with graphical symbols for each worker of the team. Numerical data can be given in numbers on the symbol, whereas Boolean data can be shown with tick marks or crosses. When for a reasonable time period, the system can show a cross above the schedule symbol, or if he will be free for three more hours, a green number three may be shown on that spot. When the cursor is placed above some field of information, a box with details on the subject pops out.



Picture 2 Table View

Requirements

This method requires automatic knowledge collection from the workers. Either this data is entered in advance, in which case the system is quite static, or there is an on-line way of gathering data, such as GPS location. The data from the customer is entered by the DM using some interface – if some part of the data is missing, decisions have to be made based on the existing data. The system itself doesn't require complete data, as it does not optimize for itself.

Benefits

This approach is very simple and intuitive. All the relevant data is shown in one view (or a scrolled view) and the best solution is easy to detect. The graphical approach with the extra information box is familiar from most computer software. As the amount of data collected is quite little, the process doesn't take much time to complete and the customer will receive an estimate for when she will be served.

Application

This method can be applied to situations, where there is a relatively small amount of workers and decisions are made only for short futures. There should also be a very limited amount of data crucial for efficient decision making.

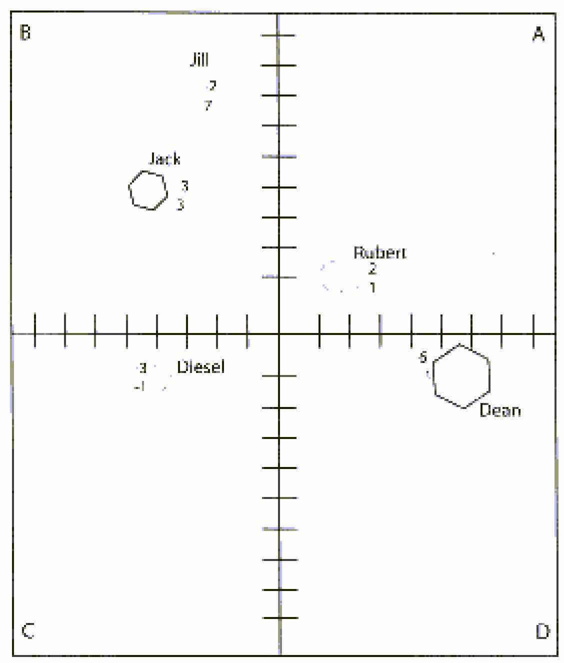
Limitations

As there is no intelligence behind the system, the human decision maker has to optimize the situation in his head. This will evidently lead to non-optimal solutions. An alternative approach could be to optimize on the basis of existing data and then suggesting the best solution by highlighting the suggestion to the DM. A clear limitation is the definition of Boolean variables. Only a limited amount of discrete options can be entered for the system to decide upon feasibility. But the combination of different options may in reality be infinite. So if a situation needs a combination of special tools or knowledge, the system may not be able to judge this. We don't however see this as a very grave limitation. If there is no on-line follow-up of the workers, this system will force decisions based on pre-determined data. However, situations may change and some customers may require a different amount of time than originally expected. These changes will not be noticed by the system, unless some extra feature is added, where changes in schedules are entered.

3.3. Matrix

Description

This model is based on visual approach where feasible solutions are shown on square matrix. This enables to show multidimensional criteria groups so worth giving the DM all the information needed to make the right solution in a very complex situation. The screen is divided to matrix, for example 2x2 or 3x3, where each of the fields has a number, letter or a word to differentiate them from each other.



Picture 3 Matrix View

The target is located on the center of the screen. Axes with some scale of measure are drawn to each side. The employees are shown some where on the matrix with marks. These marks have color and size characteristics, which are related to some criteria. Also the basic information about the employee is shown on the screen, such as name and the coordinates on the screen.

The DM will at first defines the targets criteria interviewing the customer. After this the system will draw the matrix on the screen with the employees. All of them have a mark with color and size codes to represent some important criteria. But the optimal solution is the one nearest of the target. But as the matrix is 2-dimensional, there can be multiple optimal solutions depending on the main criteria which a represented on the matrix's segments.

These will give the DM a possibility to have multiple optimal solutions from which he can made his solution depending on the main criteria he thinks is best.

Theoretical definition

This solution will enable exclusionary solution algorithms, where some criteria will divide the optimal solution calculations to some number of different forms. The number will decide to how many segments the matrix will split up.

To illustrate this for example there is a criterion to which have four feasible solutions that cannot be ranked by the system. So worth the matrix is 2x2. The location of the employee is decided on which four solutions it feats and so worth which section it belongs. The other criteria calculations will be done after that independently and the specific place on the section is so worth achieved. The colors and sizes are some key criteria depending or not from the section. The DM will make his mind up choosing one of the nearest solutions on one of the sections depending what he will think in this case is the most important optimal criteria.

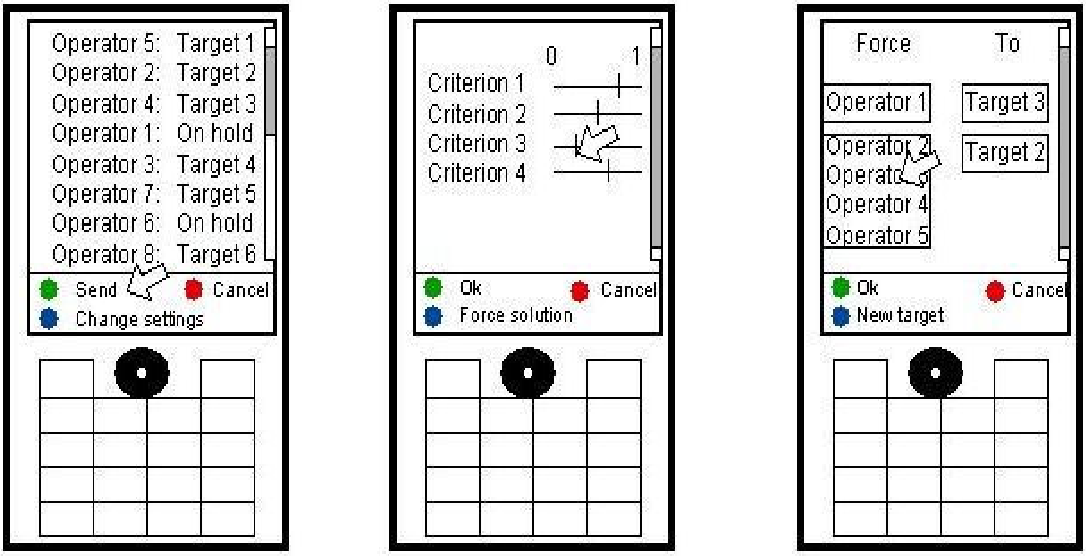
Otherwise the calculation of the optimal solution will be done on some method described on the literature study.

3.4. Traditional Decision Making with Attributes and Weights (TDM)

Description

Decision making based on multi attribute value theory has solid theoretical foundation. However utilizing directly the concepts yields rather esoteric user interface, puzzle, that could be encrypted only by specially educated personnel.

TDM-method is good at defining DSS-model which works as back-end for the whole decision making process in this research case. Thus in every changing business environment, DM can change the fundaments of the system. However, it could be used, but not too intuitively, as user-interface at the task allocation situation, if we assume that the DM is capable of a) deciding which decision criteria are needed during the specific customer contact, b) evaluating the weights for the criteria quantitatively, which might not be user friendly way, thus not viable application.



Picture 4 Traditional Decision Making with Attributes and Weights

Theoretical Definition

Traditional Decision Making with Attributes and Weights (TDM) -method is based on assumption that decision making is based on multi attribute value theory (MAVT), with possible modifications inherent to the business case. When DM has defined weights, solution can be calculated simply using the pre-defined function. Value functions can be additive and/or multiplicative and they can change dynamically.

$$Value = weight_1 \times criterion_1 + weight_2 \times criterion_2 + \cdots + weight_n \times criterion_n$$

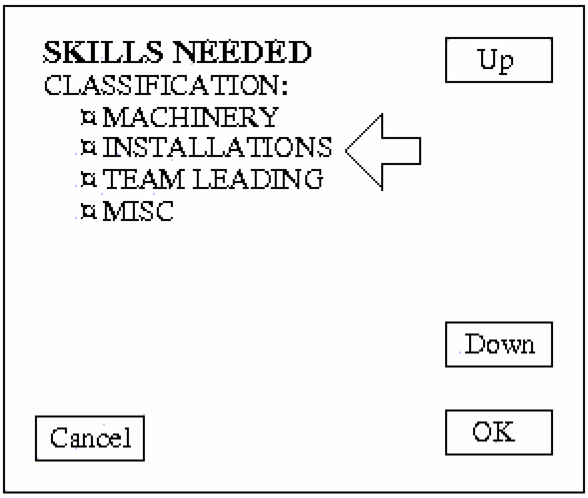
3.5. Raw Data Model (RDM)

Description

When using Raw Data Model (RDM) it is expected that user interfaces directly with decision support system database. This feature provides the most extensive way to go through all information available. Database can be considered SQL-database which has employee attributes as vectors. On the other hand every task is modeled as vector too. These vectors are matched together. DSS gives suggestion based on predefined decision heuristic.

Since direct database access is not usable in general, the "human flexibility" comes into picture. This is iterative decision making situation. Experienced manager can as most relevant questions which classifies the customer need. Hierarchy on questions creates sooner or later set of possible employees who can take the task, or points out infeasible solution.

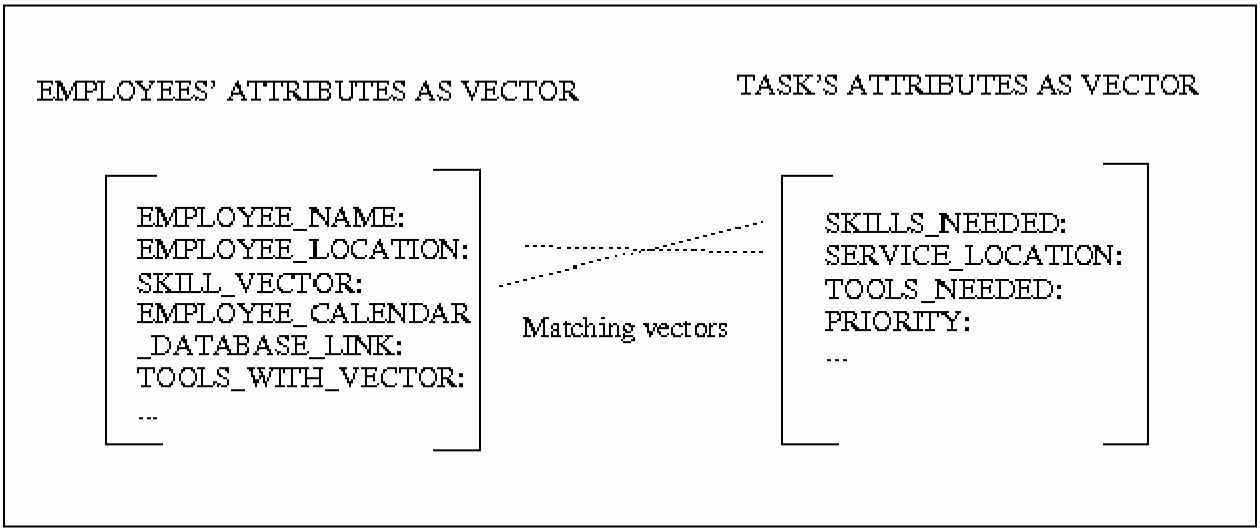
RDM is good at finding out infeasible solutions such as task which has to be done by a specialist (e.g. electrical installations). However RDM-model might end up having too many attributes for employee vector as for the problem vector. Thus RDM-method becomes too heavy to use and will not serve it's purpose. If problem vector parameters are given iteratively to the DSS, this should make the RMD-method working solution.



Picture 5 Raw Data Model

Theoretical Definition

Raw Data Model (RDM) is based on vectors. Every employee has pre-defined attribute vector which is up-to-date. During customer contact DM defines problem vector concentrating in attributes which are in relation to employee vectors. DSS compares these vectors and computes ordered list of employees most suitable for the given task. Computation is based on utility function and constraints. The ordered list is sent to the screen. The final decision is on DM.



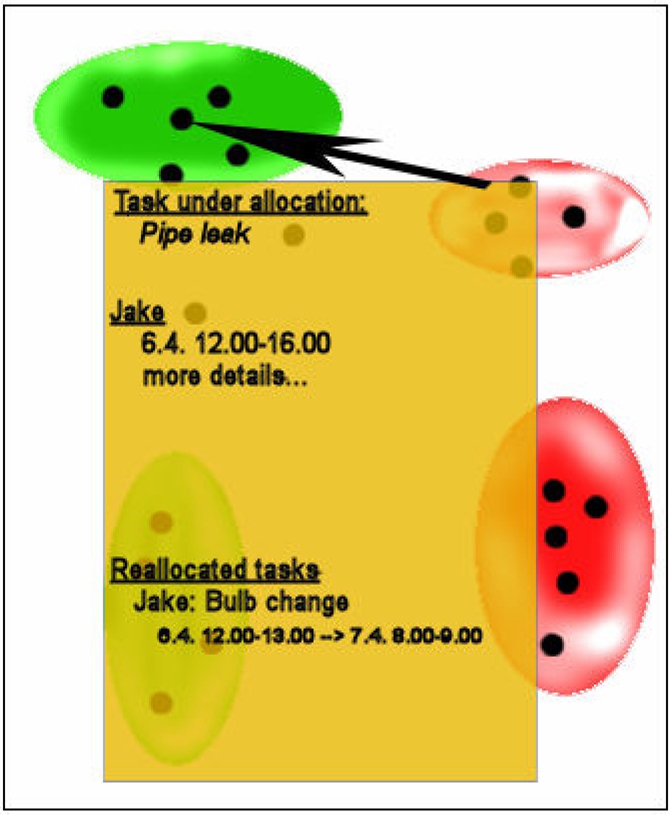
Picture 6 Matching vectors in Raw Data Model

3.6. Point Dot Cloud

Description

Point dot cloud method is based on a graphical view where best and worst matching options are separated to the clouds. Every option is represented by a dot, whose location depends on its value of attributes. Options, in which values of decision attributes are near each other, are situated near each other. Areas of the best and worst matching options are surrounded by clouds. The color of the cloud describes how good options on that cloud are matching for the current situation.

In this method the DM answers first the questions that determine the case. The clouds are formed according to answers and best matching dot is chosen as a default. Choosing and clicking a dot opens a pop-up, which gives the detailed information about the chosen option. At the pop-up window DM can allocate the task for that worker. The pop-up window also shows when the task takes place and which tasks will be reallocated.



Picture 7 Point Dot Cloud

If DM accepts the given proposition the task will be sent to the worker who has to still has to accept the task before allocation happen.

Theoretical Definition

The DSS defines the case via questions. Answers classify the case to certain class which has defined certain match with each attribute class. Clouds are refreshed according the values of utility functions after every question. Questions start from the attributes which are regarded as most important as a default.

Dots are drawn so that nearest dots has almost same values for the attributes and distance between dots tells how near the value of attributes are. The difference in values of different attributes affects to the distances between dots relative to different kind of pre-defined weights. This distance is scaled so that the whole area of the display is used.

The clouds are refreshed according the value of the utility function calculated according questions asked so far. Best matching points are rounded with shades of one color and worst matching points are rounded by the shades of another color. The shade of the cloud color describes how near the dot is from perfect mach. Respectively in a case of worst matching point the shade of the cloud color describes how far the dot is from the perfect match.

Utility function is defined so that it gives every dot a value from 0 to 100 and the value describes the amount of match between the dot and the case in relative scale. Value 100 means perfect mach. This kind of utility function can be defined classifying each attribute to the classes whose matches to each type of case has been pre-defined.

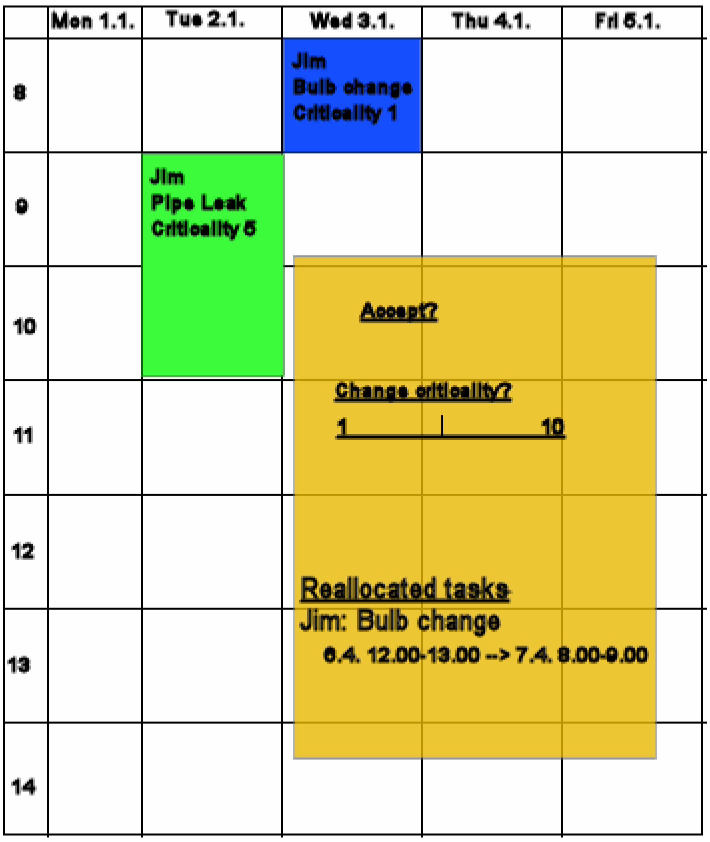
Work allocation and reallocations are done by using some of some methods described in literature study.

3.7. Schedule Model

Description

In schedule model DM makes decision using a DSS which is based on a calendar view. In a calendar view DM is able to see proposed slot for the task and affect of allocation to the other tasks. Choosing a time slot opens a pop-up window where all the tasks at chosen time slot and their criticality are shown.

The task allocation in this method begins so that DM defines the task for the DSS via questions. When the DM has answered to questions and case is defined, the DSS will propose a worker and a time slot for the task. Reallocated task will also be shown on a calendar view in some particular color. This model requires use of wide screen mobile phone such as Nokia Communicator. As the study begun it was supposed that any screen should do, but considering availability of high end mobile phone, this model was taken into account.



Picture 8 Schedule Model

If the DM feels that the proposed time slot is too late for the task he is able to browse task which are scheduled before the task he is allocating and their criticality. After the browsing DM is able to increase the criticality of the task he is allocating and after that the DSS gives him a new proposition. If DM accepts the given proposition the task will be sent to the worker who has to still has to accept the task before allocation will happen.

Theoretical Definition

In schedule model the DSS defines the case via questions. Answers define weights for the decision attributes at the DSS. According the weights the utility function gives a value for the each worker. Tasks will be allocated so that the total benefit will be maximized and after allocation the DM will be given the proposition for the time slot and worker.

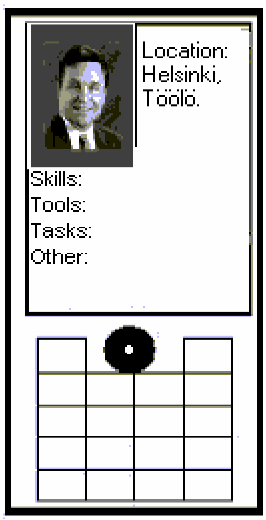
If DM thinks that current task should be done before some previously scheduled task he is able to increase the criticality of the task. The criticality is shown in absolute value so that there is always possibility to give most important criticality classification for the task under allocation.

Work allocation and reallocations are done by using some of some methods described in literature study.

3.8. Single Employee View

Description

In this model, the whole screen of a mobile phone is used to present information of one employee. The whole process starts when a customer calls to DM and DM make a few questions to get necessary data. After this the system calculate some values (like time to target) in specified server and the server send data back to the mobile phone. This data includes a little picture of the employee because illustrated data is more effective than text data. Information includes also employees name, individual skills, available tools, time to target and other scheduled jobs. Pop-up windows can be used to avoid lack of space in screen. DM is able to scroll these employee views with Next and Previous buttons. DM can make his decision with comparing and analyzing mentioned data. This model is suitable for many different task allocation management, because it allows to present various data in spite of accuracy and data type. This is one way to show employer's information. It doesn't suggest any action, it only support decision making by giving needed information.



Picture 9 Single Employee View

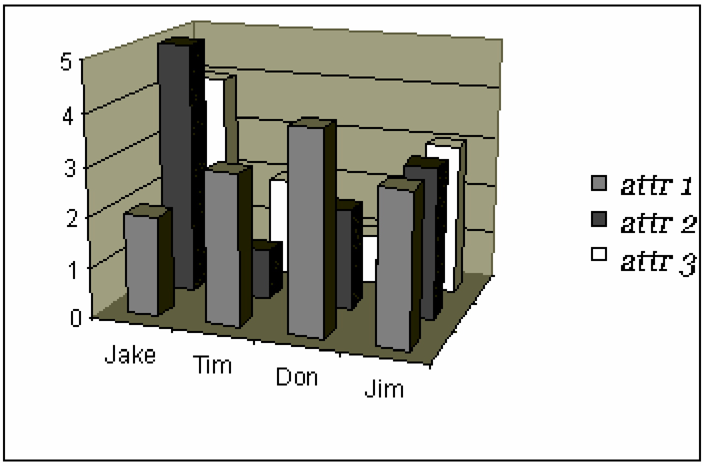
Theoretical background

This model doesn't request much background theory. The system need only one mathematical algorithm for calculating time to target. Algorithms are described in literature study. Each employers information is stored into servers' database or into mobile phones' memory. The location of this information depends on system hardware. Data layout is made so that the presentation would be as informative as possible.

3.9. 3 Dimensional View

Description

This model utilizes 3-dimensional presentation. At first DM gets necessary data from the customer. Then the data is sent to the DSS-server. The server returns result to mobile phone so that the phone can show 3-dimensional presentation. Employees and criterions are two dimensions and the third dimension describes how good each criteria is for each employee. Employees are on x-axle, criterions are in y-axle and certain values are in z-axle (as you can see in picture below). Length of the pillars describe the value of the criteria proportionally to each other. DM can look value of pillar by moving cursor on the pillar and clicking on it. Pop-up window shows the value. The idea of 3D View -model came from [Tufte, 2001].



Picture 10 : 3 Dimensional View

As Single Employee View -model, this model is another way to show attributes of employees. It doesn't suggest any action, it only supports decision making by giving needed information.

Theoretical Definition

3-dimensional presentation is quite effective way to show data so we wanted such model. Our case is based on discrete data, so pillar presentation is used in this model.

Most criterions are defined beforehand, but time to target must be calculated in the server.

3.10. Bayes Networks

Description

Bayesian networks (BN) are directed acyclic graphs, in which each variable is defined with conditional probabilities from its parents. [Bayesian Networks and Decision Graphs, Finn V. Jensen, Springer, New York, 2001]. In a BN approach, some information about conditional probabilities on effects of different decisions would exist in the system. These could then be used for uncertainty-based decision making.

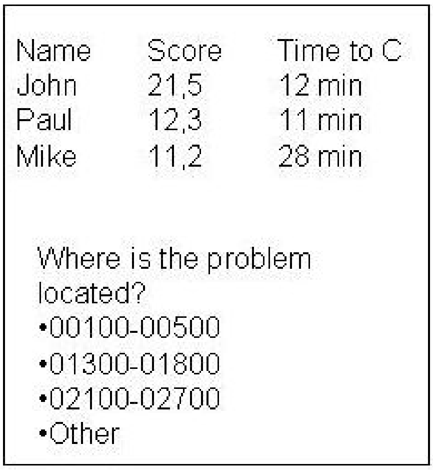
The system would be as follows. A series of pre-determined questions are posed to the decision maker. The order of the questions is such that the most influencing variables can be determined in the early phase. As the answering goes along, the system calculates – using Bayesian networks – scores for different workers. The scores are given by some pre-defined utility function. The worker with the highest score is sent to the customer. Alternatively, there is a way for the decision maker to choose which information he feeds and the system uses that information as given. This approach could be combined with an optimization method that could use the probabilistic data to produce allocations in each stage and thus produce scores for the screen.

The questions could be:

1. Where is the problem located? — Result: a probability distribution of time to customer.
2. What kind of problem is it? — Result: a distribution for the probability of success for each worker.

etc.

What the decision maker would see is depicted below.

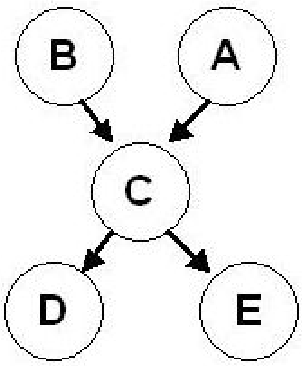


Picture 11 Bayesian View

Theory

The theory behind the BN is based on the Bayesian conditional probability formula:

$$P(A \mid B,c) = \frac{P(A \mid c)P(B \mid A,c)}{P(B \mid c)} \qquad (1)$$



Picture 12 Influence diagram

Equation (1) can be extended to form a chain rule, which defines the probability of the whole system:

$$P(U) = \prod_i P(A_i \mid pa(A_i)), \qquad (2)$$

where $pa(A_i)$ are the direct parents of the node A_i. This means that we can calculate the probability distribution of the whole system by just calculating the conditional probabilities of the nodes to their parents.

By entering evidence to the system, we will change the probability distribution and thus individual conditional probabilities. If we know all events, no conditionalities exist, and the system is deterministic.

Requirements

In order to work, the system needs a priori probabilities for the nodes. These may be gathered from historical data or estimated by experts. A very useful feature would be a learning system, which would gather data from the field and update the conditional probabilities. Other requirements are the knowledge of worker schedules and locations as well as their expertise in different tasks.

4. Comparison of Methods

At first each method is analyzed and then synthesis is provided based on that analysis.

4.1. Map visualization

Application

This approach can be applied to cases where the business is where location-orientated and localized.

Benefits

If location is the most important factor in the DM decision making process this approach is very effective one. It shows directly and intuitively who is the nearest employer. Also the direct indications showed on the marks around the employees are easy to understand.

Limitations

On the other hand this approach has got only few other dimensions that can be used by the DM. Also if the location is not important this approach loses much of its usability. The system needs the map charts and of course on time location information.

4.2. Table View

Application

This method can be applied to situations, where there is a relatively small amount of workers and decisions are made only for short futures. There should also be a very limited amount of data crucial for efficient decision making.

Benefits and Drawbacks

This approach is very simple and intuitive. All the relevant data is shown in one view (or a scrolled view) and the best solution is easy to detect. The graphical approach with the extra information box is familiar from most computer software's. As the amount of data collected is quite little, the process doesn't take much time to complete and the customer will receive an estimate for when she will be served.

Limitations

As there is no intelligence behind the system, the human decision maker has to optimize the situation in his head. This will evidently lead to non-optimal solutions. An alternative approach could be to optimize on the basis of existing data and then suggesting the best solution by highlighting the suggestion to the DM.

A clear limitation is the definition of Boolean variables. Only a limited amount of discrete options can be entered for the system to decide upon feasibility. But the combination of different options may in reality be infinite. So if a situation needs a combination of special tools or knowledge, the system may not be able to judge this. We don't however see this as a very grave limitation.

If there is no on-line follow-up of the workers, this system will force decisions based on pre-determined data. However, situations may change and some customers may require a different amount of time than originally expected. These changes will not be noticed by the system, unless some extra feature is added, where changes in schedules are entered.

4.3. Matrix

Application

Matrix approach is designed to situations where there is a very complex, multidimensional criteria problem. It demands different kinds of factors that are exclusionary to each other.

Benefits

When the situation is complex, this model will take all the possibilities in to consideration. There is a lot of flexibility concerning adaptation in to different kinds of situations.

Limitations

It demands a lot from the DM, understanding the visual side is not at all too intuitive. Also it needs a very effective background system and very sophisticated information about the industry situations for creating real optimal results.

4.4. Traditional Decision Making with Attributes and Weights (TDM)

Application

This approach is useful in many situations because it is based on basic decision making theory. Also it is generally know that this type of approach is largely used in decision making. Challenge is to examine if TDM can be suitable for decision making with mobile phone.

Benefits

Complex problems can be solved quite easily with this model. This means that DM doesn't have to be professional in decision making, model gives straight proposal for action (this feature can be positive or negative, depending on certain case).

Limitations

TDM model can't automatically take special situations into consideration, such like sudden changes or personal (instantaneous) preferences. However the system always gives action suggestion, so DM has to be well informed about these special episodes.

4.5. Raw Data Model (RDM)

Application

Vector-based raw data model is suitable specially for cases where are just few attributes. Also it is useful when tasks must be done by a specialist. However, RDM can be used in several situations.

Benefits

System compare each attribute separately. If one attribute is the critical factor, then this model can be very effective, because DM can compare only values of that attribute without help of server calculating. This model can be actually considered as a kind of blend. It include data layout form (vectors) and traditional decision making.

Limitations

We have noticed that too many attributes make this model unpractical. This problem does not limit the use of this model, it just make it non-effective.

4.6. Point Dot Cloud

Application

Point dot cloud approach is best for situations where the situation at hand can be described with answers to direct questions. Also this gives solution as intervals, which can be useful in situations where quick decision-making is critical.

Benefits

Solution is generated all the time, so that the DM can see after every answer what is the suitable solution taking into consideration the amount of answers given.

Limitations

There are limitations to that how good are the interval-solutions after each question, that is how many question has to be answered before the solution is liable.

4.7. Schedule Model

Application

Schedule model is best used in cases where employees schedule are tight and time for completing a task is quite predictable.

Benefits

The calendar view is very useful in predictable tasks so that the DM can give the customer direct information about the timetable for that ordered work.

Limitations

If task are not predictable in duration, the schedules are quite useless. The only solution is the give fair space to each task, but this will not be effective work allocation. Also the calendar view can't in great detail tell what are the criteria for each worker so that work should be quite general and not too divided to certain experts.

4.8. Single Employee View

Application

This approach is suitable for staff management problems in general, because user can define the information which is shown in a mobile phone in spite of accuracy and type. This is one way to present data, so it could be used in other situations also.

Benefits

This model brings all necessary information to DM and it doesn't suggest any action, it only help decision making by giving needed information. Also the information is shown as informative as possible. So this is a good model if computer decision making is not wanted.

Limitations

Because this model doesn't make any suggest for action, either DM has to be professional in decision making or allocated tasks must be easily approachable (DM can make his decision easily). If task allocation problem is very complex, this model is not probably the best.

4.9. 3 Dimensional View

Application

As single employee view- model, this model is also only one way to present data, so it can be applied in many different situations.

Benefits

Three-dimensional presentation is affective way to show the information. It is generally know that illustrated information is more effective than not illustrated. This approach is good, when DM has to compare proportions (not exact values) to make feasible results.

Limitations

This model does not provide direct accurate data presentation, because reserved data must be scaled before presentation. It is not usable for large number of employees, because system can not fit many employees into the screen of mobile phone. DM must have good experience of task allocation decision making to gain satisfying results. So this model is not very user-friendly from this point of view. Also very complex problems can't be solved with this model.

4.10. Bayes Networks

Application

This approach can be applied for any number of workers. With a optimization tool attached, it could solve complicated stochastic situations. It could use non-perfect data, as the Bayesian network allows it.

Benefits

The biggest benefit of this approach is the ability to cope with conditional probabilities. To answer the question: if John is free 20 km from the customer and knows something about the job and if Pete has worked for 1h at his current case, which is 5 km from the customer and he knows more about the job than John, which one should I send, given I know something about the distribution of Pete's current case time.

Limitations

Conditional probabilities may be very hard to determine, especially as individual cases may vary. A solution for this could be an approach, where instead of using pre-determined data, the workers would give estimates on e.g. work time for the case they are at and the system would use these estimates to form distributions.

5. Synthesis

The best way to compare different approaches is to use standard and commonsense criteria and to see how could does the approaches fill them.

We use to following criteria in comparing the different approaches are:

- User-friendliness; 1 means hard to use, 5 means easy to use
- Usability; 1 means low usability in the general, 5 means high
- Flexibility; 1 means low flexibility to different tasks and applications, 5 means high
- Complexity; 1 means model is suitable for simple system, 5 means model is suitable for very complex system

Methods which have same kind of characteristic will be compared to each other. That will make comparing little bit easier.

Single Employee View Model (SEV), Table View Model (TVM) and 3D View Model (3DM) are models, which are only data layouts. These models doesn't make any suggestion for action, they just present received data in different ways. SEV is little more useful than 3DM, because it gives more accurate data. TVM are almost as good as SEV. SEV is more flexible and therefore better in use.

TDM and RDM both use utility functions and weights, but TDM is more effective because it gives direct action suggestion and it can be used in very complex situations.

Each remaining model uses own theoretical or visual background. Schedule- model found out to be the best among these alternatives, because it is very useful and very user-friendly. Also this model is flexible and it can be used in quite complex situations.

These methods are evaluated in a general perspective, so that it might be in some specific cases other methods are better than the rest. Nonetheless this evaluation gives a feeling what are the most suitable methods in general.

Method	User-friendliness	Usability	Flexibility	Complexity	Sum:
Map Visualization (MV)	4	3	2	2	11
Table View (TV)	4	4	2	2	12
Matrix (MX)	2	3	5	4	14
Traditional DM (TDM)	4	2	5	5	**16**
Raw Data Model (RDM)	3	2	3	1	9
Point Dot Cloud (PDC)	3	3	4	3	13
Schedule Model (SM)	5	4	4	3	**16**
Single Employee View (SEV)	3	3	5	2	13
3 Dimensional View (3DV)	3	1	4	1	9
Bayes Networks (BN)	3	3	4	3	13

Table 2 Evaluation of methods

6. Selection of Methods

Our suggestion is based on the evaluation table above.

The Traditional Decision Making with Attributes And Weights (TDM) -method seems to be cover very well theoretical bases. On the other hand the Schedule Model (SM) -method outperforms in usability. The suggestion is to have both of them at hand. TDM can be used to change business rules since the companies have ever changing business environment, thus interacting directly with foundations of the DSS, whereas SM should be used in the everyday routines, in task allocation. Now, after the study, it appears almost intuitive result, since SM resembles shared calendar feature, or project flow view, found in many PC office environments, and it is in use and found out to be viable solution. On the other hand, TDM is about changing the form of the utility function, which prioritizes work and thus, it is about steering the company, generally considered as managerial job.

Our suggestion is based on the give case. If the forms of What, When, Where, Who questions change considerable in business processes, the model must be redefined. Because rational decision making with added human flexibility has been major point along with mobility and mathematical support in our study, we conclude that the recommendation can be considered suitable to many different service situations. Alas, no system becomes useful tool unless users have been given instructions how to use the DSS and moreover, the back-end system, where the actual mathematical computation is done, works properly, which means system maintenance and updating, also.

The suggested task allocation model requires the use of wide screen mobile phone, but on the other hand, since the mobile phone is considered as integral tool in the decision making, thus this should not be considered as feature which makes the suggestion contradictory to the primary definition which tried to found out ways which should work on any size screen. Since there are high end mobile phones which are priced modestly in absolute figures they should also be used in places where they really can make difference.

7. CASE

7.1. Introduction

The firm at hand is a service-oriented maintenance company, which has about 5-10 employees. It operates in a fairly local area, for example in some major city. Its customers are normal residents of houses, which has contracts with the maintenance company.

Task allocation is done by one operator (DM), which also is on the field as one of the workers. There is no call center or other centers for work allocation.

The mobile system is based on the recommendations from this study. It is based on the combination of the TDM- and the Schedule –methods.

7.2. Order and Allocation

The customer runs into some sort of problem and calls to the maintenance company. The number is directed to the cell phone of the DM. He asks given question from the system about the problem and dials them to the mobile. Questions from the system can be defined in an indirect way by letting the customer describe the problem. The questions from the system are very specific so that quick answers with the mobile keyboard are possible.

DM asks necessary questions so that the system can define suitable worker and a time slot for that task. This proposed worker and time slot are shown on the mobile screen and the possible reallocated other task in a different color. DM can view the proposal in more detail way choosing the time slot when a pop-up opens and more information is shown on the screen, such as what is urgency, need of special tools or profession for the task at hand.

If the proposal doesn't please the DM, he makes a different solution directly by choosing other time slot or other worker. Also he has the possibility to change the TDM –criteria behind the system by pressing for example "Settings" –button on the schedule view where from he can change weight of the criteria. After changing them the system will automatically recalculate the optimal solution proposition.

7.3. Confirmation from the Worker

When the DM has made up his mind to whom the task should be allocated, he presses the "Send" –button and the proposition is send to the worker. Now the worker has the ability to accept or deny the task. Information about the workers confirmation is then sent to the DM, who can see that the work is now allocated properly.

After the worker has done the task, the worker will dial it to the system so that the DM now sees from the schedule view what task are finished and what are not.

8. Conclusions

Some research questions that were proposed at the beginning were:

1. **How to reduce the complicated input data to such a form that a mobile user is easily able to make good decisions using the limited screen space and user interface of the phone?** — This became the prime focus of our study.
2. **What kind of models and algorithms are used for task allocation today?** — This is classical operations research and it appeared that classical methods are still good enough.
3. **Are there any such approaches that try to combine the best features of human and computer decision making?** — In the literature study we could not find any specifics about the subject but we conclude, that this is design issues, which is more of an art than science, though art can also serve as some tangible function.
4. **What is the optimum balance between human and computer decision making?** — This issue was considered out of the scope of this assignment.
5. **Is the approach of reducing the input data appropriate or would some kind of very simple decision making model be better?** — This issue was considered, but

obviously it contradicts with the purpose of the other study, when the focus became mobile phone interface with decision support system.

6. **Could the same ideas be applied to other decision making tasks?** — The suggestions given in this study point out that it is methods that are already invented that should be adapted to be used with mobile phone terminals if tangible results are needed fast. To invent a totally new framework was a good driver, but during this study it was not discovered.

The literature study revealed some issues that were of importance for the project. Firstly, no direct applications or research were found from literature. Even though we found literature about decision making in general, decision making with visual support, decision making with time constraints, scheduling and allocation algorithms, and usability of mobile terminals, no applications of mobile operational decision making turned up. The only study that brought up the subject focused on developing a special graphical language for the easy use of handheld devices as decision support systems. The lack of studies in the field of mobile decision making and therefore mobile task allocation was a surprise for us, and some studies may emerge from sources not yet discovered.

As a result of our project, several suggestions for decision support through a mobile terminal were developed. These methods ranged from traditional weighted criteria – methods to quite innovative out-of-the-box mappings of decision alternatives. The methods we found or invented showed us that there are several good ways to support a decision maker in his tasks. The most obvious methods may not always work, especially if the decision maker is not used to utilizing numerical or abstract information to make decisions. Giving weights to criteria may be fruitless, unless the true meaning of these values is understood. Then again, using verbal definitions may be difficult due to the lack of space on the screen. Using visual and graphical ways to communicate decision options and the assumptions behind them proved interesting and even though our chosen solution doesn't include that many visual effects, the other methods should be kept in mind for future uses.

The method used for comparing the different solutions was kept simple enough for the sake of transparency. The client can easily understand the logic behind the choice and – if necessary – change assumptions to see how robust our solution is. A sensitivity analysis was also conducted in order to see the limitations of our choice.

The solution we found has some relevant upsides in it. First of all, it is very intuitive for most people, as the calendar view is used in most office solutions. This helps new user in getting acquainted with the system. Still, because calendars are already incorporated in mobile phones, the system requires only minor changes and add-ons in order to work. This facilitates getting around initial hurdles in introducing the technology. By no means do we claim that the existing technology is usable without adjustments, but they are surely smaller than for some of the other solutions we found.

Lack of empirical data and testing is clearly a downside in our study. An empirical research would probably have brought important data regarding the needs of companies and managers as well as the usability of some of the methods we suggested. This study would however have required large efforts in system development. As the best way to find out how well a method works in a small screen is to use a small screen, we would have been forced to program the methods into mobile terminals. We did not see this fit into the scope or the breadth of this project. We did ask some companies that do business in suitable areas, but these interviews did not reveal anything new, except for the fact that currently used methods are very simple and based on paper and pen.

9. Future Research Directions

As a result of this study we found that the following future research directions may be useful.

Implementation and adaptation of heuristics for scheduling and task allocation

In literature study we presented different kind of approaches and methods for the scheduling and task allocation. Although we proposed that suitable heuristics could be found for the mobile DSS, implementing and adaptation of the task allocation and scheduling heuristics still needs more research.

Practical case study about usability

Evaluation of different kind of DSS approaches is based on assumptions and intuitions about the real-life working environment. Further developing of our DSS approaches should be based on responses got from real working-environment. Therefore we suggest that it is important to made practical case study about the usability of our DSS system in some kind of service sector company when this topic is studied further.

What kind of possibilities our DSS offers for different sized companies

In this project we do not commit ourselves on the exact size of the company using the mobile DSS. We have supposed in our approaches that the user of the mobile DSS is a common small or medium-sized enterprise, but the fact is that the size of the company may have a significant effect on suitability of the approach. Therefore we consider it useful to study which kinds of DSS approaches are suitable for certain sized companies.

Comparing task allocations made by using the mobile DSS to task allocations made by experienced call center worker

Companies use the mobile DSS only if they can get some benefit from it compared to traditional scheduling and task allocations. At this project we assume task allocation and scheduling problems so complicated that it is self-evident that the mobile DSS offers some benefits for the companies. However we think that it may be useful to dome research about what companies are able to gain by using the mobile DSS. This research may also give new viewpoints to developing decision making methods. One approach for this kind of study might be to compare task allocations made by using the mobile DSS to task allocations made by experienced call center worker.

What kind of possibilities our DSS offers for different fields and sectors

We presented a case example about using the mobile DSS for task allocation in maintenance company. There are a lot of other kinds of companies at service sector and completely another fields where the mobile DSS may be useful. One good future research direction may be to evaluate the suitability of the mobile DSS in different kinds of fields.

10. Project Summary

Every member in the project team was active during the project. Since all of the team members have jobs that can take them even to abroad for some days, communication was done using email and web. There were 11 project meetings vis-a-vis out of which 2 with the customer. Additionally team met in seminar sessions.

Risks that realized during the project were basically communication related: even email can have lag of days if person is abroad, on vacation, or becomes too sick. Basic issues to be learnt is that there should be prompt communication even in this size of projects.

Time used during the project can be divided to the following groups:

1. Meetings (4 days)
2. Seminar session related (6 days)
3. Literature study (4 days)

4. Writing (7 days)
5. Communication and organization (approximated 20 % overhead)

Total of 25 days.

The project deliverable to the customer is this document.

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