A Local DLP-GIS-LP System for Geographically Decentralized Wood Procurement Planning and Decision Making

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LP is an important method for allocation of wood inventory stock. It is, for instance, used alone in tactical planning systems, which currently are in wide use at the higher hierarchical level *in the functionally decentralized planning of the Finnish forest indus*try. Unfortunately, LP as a solution method has not been capable of handling spatial data that seem to characterize planning systems in geographical decentralization. In the present study, a GIS was used to assimilate data from different wood procurement functions, to calculate transportation distances and cost figures, and to write the data in ASCII files, which were then used as input for the LP model. Using the experiments and methods of GIS on a planning system developed according to participatory planning, the results of this study suggest that the participatory method was faster than the conventional LP method, when solved using actual data. The participatory method was also capable of providing the same global optimum for a wood allocation problem. The implications of these results for improving operational and tactical planning of wood procurement in Finland are discussed.

Keywords dynamic linear programming (DLP), geographical decentralization, linear programming (LP), GIS, local wood procurement, participatory planning
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1 Introduction

Decentralized decision making of the Finnish wood procurement means that some decisions are left to the lower hierarchical levels of an organisation (Keipi 1978). Further, the levels are included in decision systems to form more relevant decision-making group. For example, in the geographical decentralizing, a district of a geographical organisation can be divided into smaller distinct teams operating at the lowest echelon in the division hierarchy and independently managing their purchasing, logging and transportation operations. In functional decentralizing, the responsibilities of these operations have been almost separated based on the hierarchy, functions and the meaning of the decision (operational, tactical).

In most Finnish applications, wood procurement planning carried out at the local level of an organisation has been based on tactical decisions made at the higher hierarchical level (Palander 1993, Tolkki and Koskelo 1993). Traditionally, the local planner makes only operational decisions to control wood flow functions (Fig. 1). The lack of local tactical planning seems to be typical for the Finnish functional decentralizing (e.g. see Keipi 1978), whereas the Finnish literature on organisations has paid much less attention to geographical decentralizing, for which tactical planning and decision making could be applied at the local level. In Finland, since the late 1960's, there has been a long tradition of functional decentralizing, thereby affecting decision makers' thinking and the developed applications.

Tactical planning has been defined as an optimisation of activities of the business (utilization-rates, productivity and contracts), which leeds to the new partial adaptation or adjustment for a utilization-rate of capacity, while the overall capacity is not changed (Porter 1980, Riistama 1991). In this context, the business is defined as the wood procurement from stump to mill; the capacity is determined by the existing wood procurement plan and the budget; the contracts is defined as the market stands and the machines (productivity) owned by private contractors; the partial adjustment means that a decision-making group designs the new short-term plan.

So far, modelling of the planning systems has been limited to mathematical formulations. This means that effective rules for managing the location of the functions and inventories are lacking. Therefore, if an LP model is used in a real life situation, the number of variables and constraints increases tremendously. In procurement planning this may prevent the use of LP approaches at the local level. On the other hand, it has been found that integrated systems solved with local data would provide more accurate information because the construction of the system is closer to the real life systems (Palander 1995a,b). The future trend of geographical decentralizing would seem to require that logistics decisions be achieved only through the development of more advanced tools supporting local planning and supervision efforts.

To help expedite the process of planning wood procurement, an increasing number of articles in professional magazines have proposed to decision makers that a GIS can be used for implementation of local planning; a GIS could also facilitate supervision and management for the all hierarchical levels of an organisation (team, district, region, division). The GIS format offers several ways to enhance data management, including an efficient mechanism for data storage and retrieval, consistent and accurate calculations of area, as well as the ability to overlay and analyse features from several separate districts. So far, however, no approach that combines local operational and tactical planning has been introduced for decision makers in Finnish conditions.

In the Finnish forest industry, Tolkki and Koskelo (1993) developed a GIS for controlling trucks during the transportation function. To achieve a logistics decision, pick up schedules for the independent truckers were optimized by a separate inventory management system integrating two hierarchical levels of optimisation. All the operational and tactical computations, for example, the optimisation of the district's weekly pick up programme for each trucker, were based on the functionally decentralized planning approach that only took place on a regional basis; local data were not used directly for this purpose. Consequently, a study of geographical decentralization suggests that method of participatory planning is not used purely for the integration (see Keipi 1978).

In reality, however, the local echelons are groups (a cost centre area at the two lowest hierarchical levels) where people work as teams with a district's supervision preparing their budget themselves (Fig. 1). Therefore, the planning system should apply some participation at the local level. According to Keipi (1978), in the purest form of participatory planning, local managers and a supervisor, referred to as the "boss", prepare the plan, then the managers alone put the final plan together. In previous modelling ef-

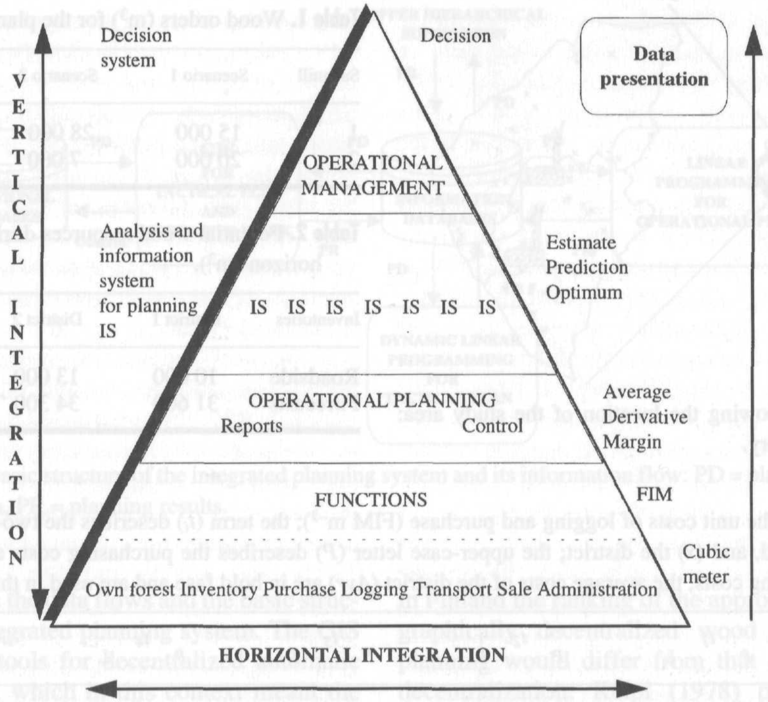

Fig. 1. Cost centre's operational information pyramid: The shadow covers the missing tactical pyramid. Geographical decentralizing provides the integration of functions (horizontal) and the integration of management responsibilities (vertical).

forts, the lack of the participatory planning has two important consequences. Firstly, the integration of individual and organisational goals may fail, since people cannot exercise control over their work (Mc Gregor 1966). Another consequence of the use of the average characteristics of a larger region over the two lowest hierarchical levels is that, if the average values are the only source of information, the allocation of function activities is incorrect. (Palander 1995b).

To conclude, avoiding participatory planning in geographical decentralization tends to lead to a wood procurement schedule that is incorrect and to a planning system that is inefficient for local integrated planning. In order to determine whether a GIS can contribute to use of an LP, the first aim of this study is to use the heuristic capabilities of a GIS to screen out potential LP decision variables that do not meet certain spatial criteria. Another aim is to design an integrated planning system which takes participatory planning into account in local operational and tactical planning. In order to determine whether the proposition of inefficiency is valid, the amounts of computing times used in the conventional and in the participatory applications are compared.

2 Integrated Planning System

Geographical decentralization was applied in the interest of large companies operating over vast areas and in independent districts, which are local cost centres that purchase, log, transport and inventory timber themselves (Fig. 1). The planning problem of the district managers was a modification of previous studies concerning tactical planning (Palander 1995a,b). This was a hypothetical problem based on information provided

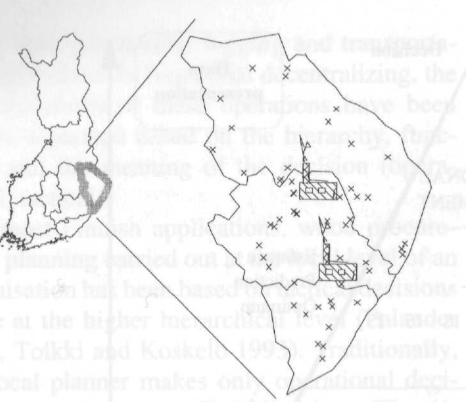

Fig. 2. Map showing the location of the study area: x = inventory.

Table 1. Wood orders (m³) for the planning horizon.

Sawmill	Scenario 1	Scenario 2	Scenario 3
1	15 000	28 000	7 000
2	20 000	7 000	28 000

Table 2. Potential wood resources during the planning horizon (m³).

Inventories	District 1	District 2	District 3
Roadside	10 000	13 000	3 000
Forecasts	31 600	34 300	24 500

Table 3. The unit costs of logging and purchase (FIM m^{-3}); the term (t_i) describes the two-week time period, and (x) the district; the upper-case letter (P) describes the purchasing costs and (L) the logging costs; the average costs of the district (Avr) are in bold fase and are used in this study.

x	t_1		t_2		t_3		t_4		Avr
	P	L	P	L	P	L	P	L	
1	120	50	120	60	120	70	140	100	**195**
2	120	60	120	70	120	80	140	110	**205**
3	120	70	120	80	120	90	140	120	**215**

by the Finnish Forest and Park Service, in which the cost level included in the data was for the year 1991 from week 36 to week 43. To solve the problem, the integrated planning system was developed from this material, which consisted primarily of the information covering three geographical districts in North Carelia (Fig. 2). Further, the districts will be divided into three distinct teams to provide the local participation.

The problem was solved by minimising the costs of the wood procurement operations. For both study methods the wood order of the planning horizon was a very important criterion: for the spatial allocation method done by the GIS-LP in the participatory application, and for the allocation method done by the LP in the conventional application. Assessment of the wood orders as the inputs for the study system was restricted to two sawmills. In a real situation the wood order could be derived from the sawmills' desired production of sawn goods, but here the sawmills' minimum demands were based on Table 1: For the basic scenario one, the demands for spruce sawlogs amounted to 15 000 m³ and 20 000 m³, respectively.

In each district (x_i), there was wood at the roadside, termed "roadside"; this wood was available for transportation at the beginning of the planning horizon. The future transportation potentials were visualized through forecasts made by district managers: Their forecasts were based on both their experience and the standing inventories (stumpage timber). In this system, the potential wood resources were called "the inventories"; these are presented in Table 2.

The costs of wood procurement consisted of two separate compositions. Firstly, there were costs preceding the roadside inventory; these were divided into costs derived from purchasing and costs derived from logging (Table 3). The logging costs also included hauling costs. Secondly, there were the transportation costs, whose model structure will be considered in more detail in the methods section.

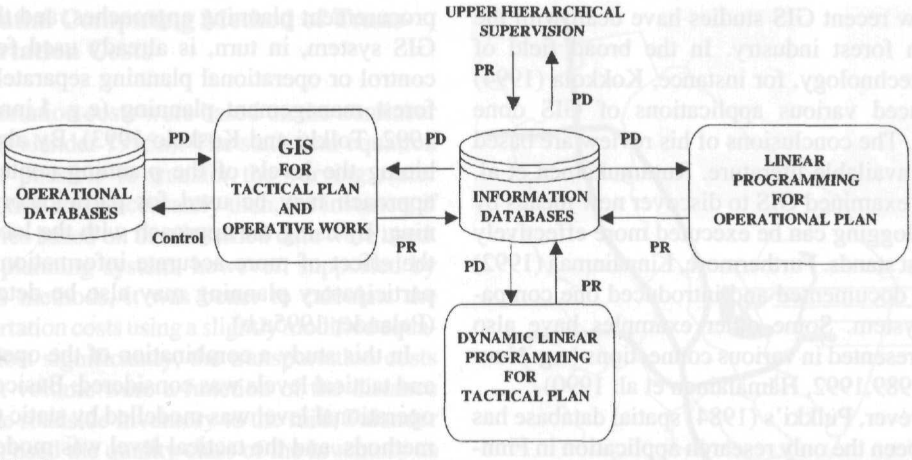

Fig. 3. Basic structure of the integrated planning system and its information flow: PD = planning data, PR = planning results.

Fig. 3 shows the data flows and the basic structure of the integrated planning system. The GIS provided the tools for decentralized automatic data handling, which in this context meant the data treatment at the local districts (Palander 1993, Tokola et al. 1994). These data were used in various conversions (cubic metre, ..., estimate) for the operational management and tactical planning (Fig. 1). Consequently, the system integrated the respective levels of database development, the operational and information databases. The operational database could be used to manage spatial local data for the allocation method, and the information database could be used both by local management and in upper hierarchical supervision. In this system, the information generated could also be used to set tactical constraints for the operational planning and to allocate inventories in the implementation phase of the planning process.

3 Methods for Incorporating Participatory Planning Into the System

There are several potential participatory approaches to modelling the local planning system, which are reviewed before participatory and local planning is related. It is to be expected that in Finland the ranking of the approaches of geographically decentralized wood procurement planning would differ from that of functional decentralization. Keipi (1978) presented approaches for the top echelon's functionally decentralized planning. In the same context, he proposed that discrete simulation due to its flexibility and goal programming due to its robustness may be ranked high for geographical decentralization. The shortcoming is, however, that the operative transportation control is not easy to construct and that it is not completely known how much the integration of the local functions increases the amount of modelling work (Fig. 1).

A further shortcoming is connected with the estimation of the operational spatial costs of the functions, because the mathematical approaches do not deal with the location of the functions and inventories. This can be overcome by calculating costs using map algebra from the stand locations to the mill locations with the GIS method of Tomlin (1990). When this is used in a GIS approach, a new cost value is computed for each location as a function of existing values: from locations, from other layers, from zones in layers, or as an increment of one-, two- or three-dimensional cartographic forms. Unfortunately, one aspect that prevents the direct use of spatial costs in local planning and decision making is that at the moment there are few GIS approaches in Finland.

A few recent GIS studies have dealt with the Finnish forest industry. In the broad field of forest technology, for instance, Kokkola (1994) introduced various applications of GIS done abroad. The conclusions of his review are based on the available literature. Rummukainen et al. (1994) examined GIS to discover new means by which logging can be executed more effectively in forest stands. Furthermore, Linnainmaa (1992) briefly documented and introduced one company's system. Some other examples have also been presented in various connections (e.g. Nuutinen 1989,1992, Hämäläinen et al. 1990).

However, Pulkki's (1984) spatial database has so far been the only research application in Finnish conditions. Pulkki solved the problem of long-distance transportation of wood by means of a heuristic programming system. With heuristic ruling of the transportation network, the problem could be solved efficiently. A disadvantage is that this third approach gives only the solution for the partial function of the wood procurement. Therefore, the coordination of the districts' functional plans into one final plan refers to the functionally decentralized approaches instead of the given approach of pure participatory planning.

The publications above also introduced various combined GIS approaches, but these approaches have been developed in North America, where forest ownership and working conditions differ from those in Finland. In most cases the North American systems combine forest management and wood procurement planning. Although it has been found that GIS can be used to good advantage in forest management planning, this fourth approach is not the normal and possible strategy in actual planning situations in Finland. In fact, only the Finnish Forest and Park Service, the organisation entrusted with stewardship of the state-owned forests, is similar to the North American organisations. Therefore, if a local planner in the Finnish forest industry wants to develop the participatory planning system, then the importance of a combined approach including GIS and forest management planning should not be given excessive emphasis.

In the Finnish forest industry, however, the approach for using local information in participatory planning could be a combination of LP and GIS; LP methods are mostly used in wood procurement planning approaches, and the pilot GIS system, in turn, is already used for daily control or operational planning separately from forest management planning (e.g. Linnainmaa 1992, Tolkki and Koskelo 1993). By also combining the levels of the planning context, this approach may be used for participatory planning; by using the approach with the local data, the effect of more accurate information on the participatory planning may also be determined (Palander 1995a,b).

In this study a combination of the operational and tactical levels was considered: Basically, the operational level was modelled by static GIS-LP methods, and the tactical level was modelled by DLP. DLP was applied for two reasons: Firstly, tactical planning cannot operate without the dynamic consideration of time factors (Palander 1995a), and secondly, therefore the method used to solve such a problem had to be some type of dynamic method or its approximation.

Although, the participation in the tactical planning context of the Finnish forest industry has yet to be considered, it can be contended that an upper hierarchical level controls and coordinates lower level's management operations via participative decision making (Keipi 1978). To incorporate participatory planning in the models used, the local decision-making group uses the interactive planning system. Further, the district's supervisor coordinates the planning process and facilitates the use of computers for teams' managers. The number of participants of the group can be between four and ten. All persons, who are related to the planning problem, use the programs and participate in the choice aspect for reaching a consensus.

This approach also had the advantage that no additional research was needed to implement the system. Only the methods of tactical selection of the inventories had to change for GIS and be combined with the DLP system because conventional LP methods alone did not include options for spatial allocation. Therefore, this approach was used in this study to examine the effect of participatory planning on the local management; it was referred to as the "participatory approach".

3.1 Spatial Computing Method of Transportation Costs

Transportation costs were based on the nonlinear model (Palander 1995a). The statistical equation made it possible to transfer the varying raster information more accurately than, for instance, if categories based on the classified data were used. In this planning system, however, supported by the GIS methods, it was better to calculate the transportation costs using a slightly modified equation. Most significantly, the transportation costs per unit volume were a function of the distance from the roadside inventory to the mill; Palander (1995a) used the quality class of the inventory as another explanatory variable. Here, both variables were replaced by one distance variable that was related to the transportation time. Thus, the equation has the following format:

$$TRANSP.mk = \alpha + (15.62 - \alpha)\exp[-\beta \cdot (\gamma \cdot TRANSP.km - 5)] \quad (1)$$

where:

$TRANSP.mk$ is the cost of transportation,

$TRANSP.km$ is the distance of transportation,

α, β are function parameters,

γ is the time parameter of transportation.

The quality class of the inventory was replaced by the transportation time because, in Finland, the quality class is actually affected only by the road class. Today, the significance of the other factors has decreased. In this new situation the transportation time (weights) combined with transportation distance explained the transportation costs per cubic metre with the same accuracy as the prior model did.

In the first step of the computation, transportation time was defined according to the method of weighted unit coverage (Fig. 4), which was utilized using the means of the map algebra. Actually, the road map could be imagined as a "raster network" containing four possible levels of the map feature (road class I, road class II, land, water); the "impedance" of the network was expressed in terms of the transportation time (elevation).

In the next step of the computation the transportation distance from a mill (the starting point)

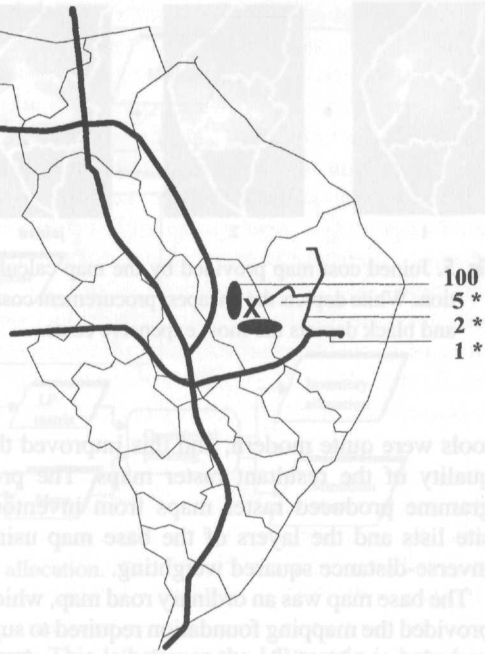

Fig. 4. Principle of weighted unit coverage.

was weighted by the transportation time: 1 for the raster of road class I, 2 for the raster of road class II, 5 for the raster of all other roads, and 100 for the raster of water. These weights had two effects on the computation. Firstly, the transportation costs were more accurate. Secondly, transportation used roads instead of lakes or forests. Then, during the computation, the transportation distances were transformed to transportation costs; the shortest cost paths were added up dynamically using this distance model on the cost-layer. Finally, the best choice was used to compute the transportation layer for both mills.

3.2 Interpolation and Estimation of Cost-layers

Interpolation was used as the method of surface approximations with spatially located data. The programme s.surf.idw in GRASS was used as the tool, since using it was convenient and suitable for presentation of the cost-layers of this planning system. In addition, GRASS-supplied

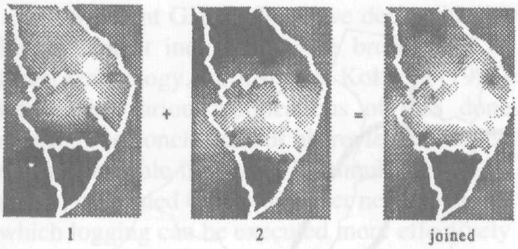

Fig. 5. Joined cost map provided by the map calculation: White depicts the cheapest procurement costs, and black depicts the most expensive costs.

tools were quite modern, and this improved the quality of the resultant raster maps. The programme produced raster maps from inventory site lists and the layers of the base map using inverse-distance squared weighting.

The base map was an ordinary road map, which provided the mapping foundation required to support the needs of the group decision makers. This map supported a more diverse multiple-layer database: It directly supported layers composed of the base map features such as road layers, for example, and as an indirect support, the features were used as guides for locating additional features, such as mills and district inventories.

The total cost-layers for both mills were interpolated based on the procurement costs of the inventories, in which the transportation costs were an important factor. The variation in the purchase and logging costs was slight since the costs were calculated as averages for the district data. The use of data from the rural teams of the districts, such as the use of transportation costs, would provide more sensitive analyses and proper informative interpretation for decision makers; this is the aim in future. In this preliminary system, decision makers affected the choice of inventories during the visual participatory process. However, the use of district data provided more accurate cost-layers than region data.

Interpolated maps were joined by the following formula to identify the predictive cost value in Finnish marks (FIM) between the separate cost-layers of both mills. As usual, one mill had a larger wood order than the other. In order to emphasise the procurement costs of the mill, the coefficient was calculated as the ratio of the mill's actual wood order to the total sum of wood orders. Such a calculation provided the information needed to determine the joint cost-map to be used when the map was displayed for manual selection of inventories (Fig. 5). The formula had the following format:

$$join = (coeff.1 \cdot pcost.1) + (coeff.2 \cdot pcost.2) \qquad (2)$$

where

join is the predictive cost value,
coeff.i is the coefficient for mill i,
pcost.i represents the procurement costs for mill i,
$i = 1,2$.

3.3 Participatory Planning Method

The participatory application represented the pure participatory method of planning introduced by Keipi (1978): Firstly, the local managers with their supervisors prepared a basic plan using tactical planning; and secondly, the managers put the final plan together using combined operational and tactical planning (Fig. 6). The basic plan for districts has been introduced in the previous study (Palander 1995b). The final plan can be defined as the operational participatory plan, which allocates inventories for a decision-making group with the minimum costs.

Participatory planning was implemented by the interactive method that selected the inventories for wood procurement. This method was developed for GIS because the conventional LP method of allocation alone did not include combined planning and spatial allocation of inventories. In the conventional application, tactical planning done by DLP preceded the allocation method done by LP, whereas, in the participatory application the part of tactical planning, resource investment analysis, was combined into the method by GIS; this first planning stage followed reduced DLP, but preceded LP. The mathematical formulation of the DLP model has been published (Palander, 1995b).

The resource investment analysis means that the participants consider the interesting resource relations of the basic plan because, quite often, in practical systems, linearity of constraint ine-

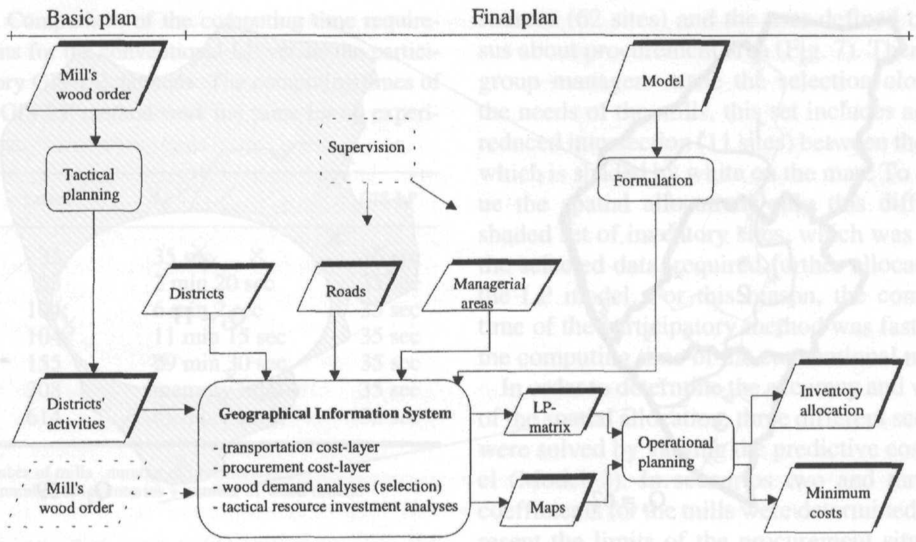

Fig. 6. Overview of stages for operational inventory allocation.

qualities and the object function can limit the usefulness of models. This should be given serious consideration. Linearly in object function means that cost per unit of resource remains constant regardless of the amount of wood orders. Similarly, the total volumes of resources transported from districts to mills are assumed to be a linear function of the amount of wood orders.

Fig. 6 describes the implementation of the study method with the data storage and its planning stages in the limited part of the participatory application, referred to as the "final plan". The wood orders and the results of tactical planning were used as the criteria in the interactive GIS allocation. This second stage was referred to as an interactive wood-demand analysis of the GIS. In the demand analysis the participants manually select the area (inventories) from which procurement are done. In addition, the demand analysis was subjected tactically to the districts' minimum procurement volumes, defined by resource investment analysis.

In the computer programme, the planner pointed at the desired cost zone around the mills on the display screen with the mouse pointer. Care had to be taken so that the digital raster map formed inside the zone included enough inventories for both mills to guarantee the global optimum. This is because the LP matrix is based on this manual selection. In the reality, there may be not enough inventory inside the area of the decision group to achieve the global optimum by the conventional application.

Before the LP allocation of inventory sites, the exclusion areas of the procurement cost-layers were eliminated from consideration using a heuristic rule. Further, the new set included reduced intersection between the mills, which is shaded by white on the map (Fig. 7). This third stage selectively reduced the amount of LP inventory data that needed to be allocated later. Therefore, this spatial inventory selection was one of the most important features of the participatory planning method.

The data were entered into the LP model via its LP matrix, which was in an ASCII file. Before transformation, this file, initially created by the GIS, was stored in the information database, in which the file was reformatted into the ASCII file: formatted in a manner specified by the commercial QSB programme, and containing the parameter data in a form accessible by the LP model. This conversion also required the use of a C++ routine, developed in-house, that read and formulated the file, inserting appropriate zeros or unit values for parameters not supplied by the GIS. After this, the file needed only to be export-

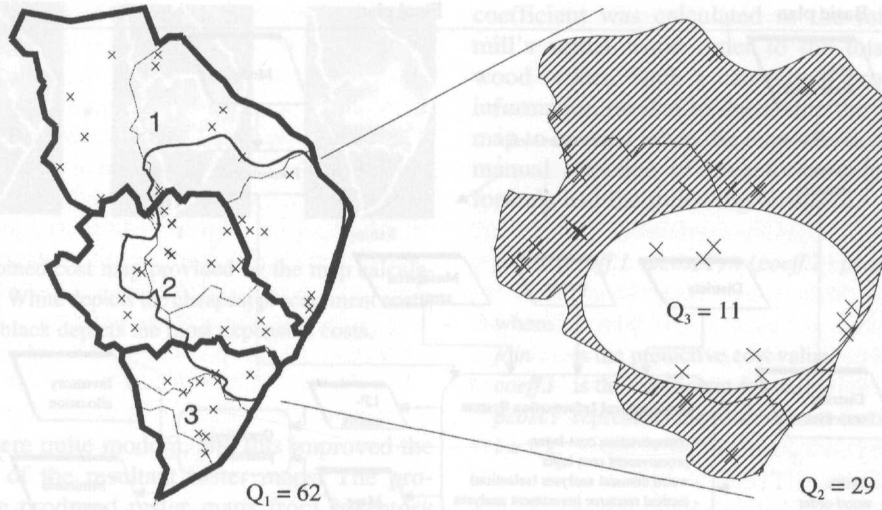

Fig. 7. Simple digital map made by heuristic selection of inventories in GIS: Q_1 = region's inventories, Q_2 = group's inventories, Q_3 = inventories between the mills.

ed to a PC, where it could be read and solved by the following simple LP model.

$$Minimize\ Z = \left[\sum_{t=1}^{T} \sum_{k=1}^{K} \sum_{j=1}^{J} \sum_{i=1}^{I} (ca_{ijkt} A_{ijkt}) \right] \quad (3)$$

inventory allocation

subjected to the following restrictions

Mill wood order

$A_{ijkt} \geq D_{ikt}, \quad \forall\ i,j,k,t$

Non-negativity

$A_{ijkt} \geq 0$

where

Z = optimum total costs (FIM),

D_{ikt} = volume (m^3) of wood grade i required by mill k during period t,

A_{ijkt} = volume (m^3) of wood grade i delivered from inventory j to mill k during period t,

ca_{ijkt} = timber procurement cost per unit volume (FIM/m^3) of wood grade i delivered from inventory j to mill k during period t,

T = number of discrete periods (two weeks) of planning horizon,

K = number of mills,

J = number of inventories,

I = number of wood grades.

4 Results

In the first analysis, the design used consisted of seven simple experiments that demonstrated the use of the planning methods and their requirements for computing time. The results of the comparison of computing times are presented in Table 4, which permitted comparison of the efficiency of spatially (GIS-LP) and nonspatially (LP) determined inventory allocation. This analysis allowed for the characteristics of the participatory and conventional methods, respectively.

The first experiment contained 62 variables and 33 constraints; this corresponded to the case with two mills, 31 inventories and one timber grade. The second differed from the first in that it had more inventories; it was also the basic case used in the maps and analyses. The largest case solvable by the LP procedure allocated 153 inventories: 306 variables. There was a potential of 600 inventories within a planning area, but these could not be solved because the DOS environment used did not allow the use of large LP matrices.

All the experiments had to result in the same

Table 4. Comparison of the computing time requirements for the conventional LP versus the participatory GIS-LP methods: The computing times of the GIS-LP method were the same for all experiments.

Var.	Constr.	LP	GIS-LP
62	33	35 sec	35 sec
102	53	2 min 20 sec	35 sec
102	104	6 min 2 sec	35 sec
204	104	11 min 15 sec	35 sec
306	155	29 min 30 sec	35 sec
612	308	memory limit	35 sec
1224	614	memory limit	35 sec

Var = number of mills · number of inventories;
Constr. = number of inventories + number of wood orders.

optimal solution because the purpose was to compare the computing times instead of solving the problems. Therefore, the mills' wood orders and the districts' procurement needs, as well as other characteristics for the system, were replicated as constant; this explained exactly the same computing time values for the participatory method. On the other words, the size of the experiments was not noticeably related to the computing time. Actually, the number of variables (LP-model size) varied slightly for visual selection without any marked effect. Nevertheless, in all experiments the participatory method performed better because of reduction in the model size.

The model size for the participatory approach never varied because the spatial allocation included manual selection, also referred to as "visual selection", which was combined into GIS by adding a heuristic rule. To adopt the rule, GRASS was used to combine polygons and raster maps with each other based on set operations, such as "UNION" or "INTERSECTION". This stage of the participatory method was known as "topological overlaying", and the result was a new digital map, or coverage.

The following example clarifies the spatial allocation by showing what actually differs between the two approaches in terms of GIS. In this second analysis, after the demand analysis, the heuristic rule resulted in a selection (29 sites) that was the intersection of potential wood resources (62 sites) and the user-defined consensus about procurement area (Fig. 7). Then, if the group managers made the selection closely to the needs of the mills, this set includes accurate reduced intersection (11 sites) between the mills, which is shaded by white on the map. To continue the spatial allocation, only this differently shaded set of inventory sites, which was part of the selected data, required further allocation by the LP model. For this reason, the computing time of the participatory method was faster than the computing time of the conventional method.

In order to determine the accuracy and validity of the spatial allocation, three different scenarios were solved by varying the predictive cost model (Model 2). In scenarios two and three, the coefficients for the mills were determined to represent the limits of the procurement situations. In all scenarios, the same numbers indicated the inventories. As shown in Table 5, the number of overselected inventories needed ranged from two to six. This difference was noticeable, although fairly small.

Table 5 also gives the total number of selected inventories: the sum of the overselected inventories by GIS and the allocated inventories by LP. These inventories indicated the minimum set of the required number of inventories, which yielded the global optimal solution. For scenarios two and three, manual selection using the resultant maps had to be ample because the wood order of the mills were satisfied by using desired cost zone around the mills. Here, wood procurement of one mill was more difficult than wood procurement of the integration of both mills.

LP was also used as the reference method in the analysis of validity. These findings are also shown in Table 5. The differences in the inventory allocations were in the right direction because the changes in allocation were strongly related to the changes in the mills' wood demand (see Model 2). The inventories missing from some other scenarios were shown in bold print, whereas the inventories written in normal fonts were the same for all scenarios.

Table 5. Validity analysis of the interactive selection procedure: Coefficients depict a mill's wood orders as respective proportions of the total wood procurement in Model 2.

Scenario no.	Coefficient for mill 1	Coefficient for mill 2	Overselection of inventories by GIS	Inventories allocated by LP[1)]
1	0.43	0.57	17,18	1,2,3,4,5,6,7,8,9,11,**12**,13, 14,**15**,16,19,20,30,31,32, **33**,35,36,**37**,38,39,47
2	0.8	0.2	33,40,18,37,43,48	1,2,3,4,5,6,7,8,9,11,**12**,13, 14,16,**17**,19,20,30,31,32, 35,36,38,39,**44,45,46**,47
3	0.2	0.8	10,12,18,43,40,42	1,2,3,4,5,6,7,8,9,11,13,14, **15**,16,**17**,19,20,30,31,32, **33,34**,35,36,**37**,38,39,47

1) The inventories missing from some other scenarios are presented in bold print.

5 Discussion

The primary purpose of this report was to discuss the integrated planning system by which the participatory planning approach was taken into account in local planning of wood procurement. The present study focussed on analyses of the accuracy and efficiency of the system instead of a discussion of integration of the elements: data/information handling, optimisation, and spatial methods. These main characteristics were used to improve the efficiency. Furthermore, the method applied provided a heuristic environment that fully supported an organised approach to operational "real-time" management, analysis, interpretation and presentation of spatial data. By this method, moreover, operational and tactical planning levels could be partly combined.

In the participatory approach not all important human interactions were replaced by computer algorithms. Selecting the best course of action was not the responsibility of a single individual because the group interpretation of the best course of action reflected a consensus of the individual opinions about the inventories. The individual (team) preferences were aggregated into a single group or consensus preference. According to Sen (1970), this aggregation requires three distinct, yet interrelated activities. In this context they were applied to stages of GIS. Firstly, the team preferences were shown by the resource investment analysis. Then, the inter-group preference comparison and the group preference determination were combined and applied by the demand analysis and the heuristic rules.

In the present study it was found that the spatial allocation of the participatory method could speed up the local planning of wood procurement, which is conventionally performed only by LP models. It was found that the participatory method performed relatively faster in cases that demanded procurement of a small proportion of potential inventories; the smaller the proportion of selected inventories, the better is the performance of the method. Although these findings supported the expectations, a limitation of this analysis should be mentioned. Unfortunately, the method may not at all appear to be sensitive to the size of the allocation problem because the experiments were simple multiplicative forms from the basic experiment; the sites of the new inventories were the same in the bigger experiments. More research should be undertaken to either prove or disprove the expected dependencies on problem specification.

Because the findings were based only on simple experiments, the present results suggest that the participatory method can be recommended at least for short-term planning of operational and tactical wood procurement. In local units the volume of the mills' wood order represents a small proportion of the total inventory stock during short planning periods.

As expected, the participatory method was highly useful for removing exclusion areas from large regions: Once the user reduced the data, the subproblem (intersection) could be solved by the LP model of the present commercial QSB programme. In addition, the results indicated that an ordinary PC with DOS was not suitable for processing the large amount of data in an LP matrix, due to the limitations imposed by the hardware and the accessible memory under DOS. This problem could be avoided by using a compiler with DOS extenders or new operating systems such as Windows 95+NT. Further, with the rapid decline in cost of computing power, this may not be a problem for long. However, it was an actual problem in the local units because of lack of the following resources: effective computers, programming skills, and replacement investments, such as adequate RAM on the machine.

There were several potential participatory approaches to modelling the local planning system, which were reviewed before participatory planning and local planning were related. Some transportation problems which use LP were also introduced. Although, it can be argued that inventories' coordinates can be used to form the cost structure of the transportation problem of LP, the GIS was needed to contribute to the participatory use of LP. Further, the planning system was used for participatory planning in local operational and tactical planning. Although, this study cannot give decision makers "tradeoff" between these methods, the preliminary results suggest that the participatory method was faster than the conventional LP method.

The results of the analysis of the accuracy and validity of the participatory method show that the use of GIS selection before LP allocation could provide the same global optimum as the conventional LP allocation. In these solutions, wood procurement costs were a function of the mills' periodic demand for wood; if the demand must met by procuring inventories from the wrong locations or during the wrong periods, extra costs are incurred. Therefore, using an accurate model for selection of the inventories was critical to the effectiveness of the participatory method. Although Model 2 was rough (simple), it together with manual selection provided a prediction accurate enough for LP allocation. However, it clearly appears that allocation by the GIS-LP methods is able to provide valid information for preparing excessively large problems, even for ordinary programmes and computers.

In this analysis, it was assumed that the same location of inventories, generated by multiplication, applied to all scenarios for mills' wood demand. Of course, the location of the inventories can vary randomly during the planning horizon, and therefore wood demand would be met from different locations. Further, selection between the mills seemed to be fairly obvious. To compensate for this shortcoming, planners overselected the inventories manually. Further tests should be planned to refine the selection technique by means of demand models, thereby improving the method.

The question of what happens to the inventories that are not selected and included in this schedule is an interesting one. Of course, some of them would be procured during subsequent periods, especially inventories that are already at the roadside. For these inventories and for those stored in standing and logging buffers, a tactical plan would provide the order and timing of the next operations. Moreover, in this hypothetical problem, it was assumed that the volume of purchased inventories was predicted by district managers. Therefore, the method includes some risk, but at the same time provides an interesting possibility for use in the management of purchases.

The potentials of the GIS can, however, be turned into reality only if this technology is made easy for the actual planners, who need not be GIS specialists. This is particularly true at the local level. As the present study suggests, it may then be possible to develop methods of GIS that can be implemented to provide the potential for heuristic planning and flexible control. On the other hand, combined with the INGRES database, for instance, it could also provide a useful tool for specialists (organisation's experts) to use for conditional selection operations for the periods of the planning horizon.

This study dealt with the local cost centre of a typical Finnish forest industry, in particular, its participatory planning application. These research findings should be applicable to forest industry outside Finland if an organisation wants to presuppose the structure of the operational information pyramid to be like that showed in Fig. 1. Nevertheless, it would appear to be critical for successful geographical decentralization of wood procurement planning to at least take into account the sequential description of wood flow functions (Palander 1995b).

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