ABSTRACT
The paper elaborates foundational principles of planning, specifically in the field of container stowage planning. The efforts in methodological development to automate the process of planning often involve translating the knowledge of planning into a rigid formulation of mathematical models or logical if-then rules.

Two models are developed in order to raise our understanding on planning. The models show few important notions of planning principles: a) planning is a problem-solving task, which has often more than one equally feasible solutions, b) capability & speed of performing planning task improves in line with the degree of resemblance of current task to previous known tasks.

Those findings are of a great importance to determine the strategic direction of methodological development to automate stowage planning. It addresses on how automatic should be a future intelligent stowage planning tool.

KEY WORDS
Wittgenstein's Picture Theory of Meaning, Theory of Planning, Case-Based Reasoning, Stowage Planning

1. Introduction
Stowage planning is an act of arranging container boxes on board a ship. To accomplish this, aspects such as stability and strength of ship at departure and arrival, loading list at port of loading and at next ports of call till restows are considered.

Today, stowage planning software assists planners by providing tools to calculate stability and strength, restows, cranesplit and a facility to check the stowage of hazardous cargoes. The planning processes are assisted by those tools.

Those tools visualize the process of planning and provide information whether a plan has desirable properties (stability, strength, etc) or not. They still do not assist the planner, how to solve the problem, if those properties do not satisfy the problem. They do not give any hint which containers and where to be stowed.

Addressing foundations of stowage planning lead us into previous works in philosophy, where addressing the 'definition of a good stowage plan' stands at the the foreground. This paper elaborates in particular the philosophical foundations of the Casestow1 – a case-based stowage planning system for container ships [1, 2, 3].

2. Roots in Philosophy
Defining 'what we understand under a good stowage plan' seems to be the origin the problem, both from philosophical and practical viewpoints. Wittgenstein argues that defining an object precisely and objectively is hardly possible [4, 5]. An object is polymorphic. The findings from the practice of stowage planning confirm this: experienced planners cannot define 'a good stowage plan' precisely and consistently. Even two stowage planners may prefer different solutions for the very same planning problem.

Commercial considerations may play a more important role than the operational ones. It is not unusual that an important client requires his containers to be stowed at specific slots. Stowage planning involves a decision process. In such a situation, sales department or a marketing director may decide it.

Comparing an object with another is simpler, argues Wittgenstein. An experienced planner recognizes if a stowage plan is good or poor. Comparing two stowage plans is easier, which one is more preferable over the other.

The more plans he has made, the quicker he creates a new plan. Knowledge improves every time he solves a planning problem.

Most of approaches of automating the stowage planning process is based upon the reasoning that the task can be translated as an array of mathematical formulas or if-then rules [3]. Apparently there is still no single method that has successfully addressed the task of automating stowage planning activities.

In spite of the complexity of the planning task, a plain fact from practice is that an experienced planner views planning tasks easy. He knows quickly how to accomplish a new planning task. He may try few plans before he finds a satisfactory solution. He uses few plan concepts selectively to solve a new planning problem, before he arrives at a new stowage plan.

The planning paradox is: on one hand, planning a complex and knowledge-intensive task, on the other hand most planning tasks are viewed as relatively easy tasks as they are a routine job.

Consider the fact that humans are robust problem-solvers; they routinely solve hard problems despite limited and uncertain knowledge, and their performance improves with experience. These facts are strong reasons, to raise understanding on how a human views planning tasks and how he solves them.

Those properties are desirable for real-world Artificial Intelligent systems [6]. The Artificial Intelligence can be a promising gate towards addressing stowage planning problem.

3. Planning Simulation

3.1. Model 1

The objective of the first model is to prove if similar planning problems reoccur. It is to show the role of reoccurence in planning processes, how it is used to solve planning problems.

A ship is scheduled to serve two regions, A and B. The task is to develop a stowage plan at a loading port A1. The ship sails to region B, she calls ports of discharge B1, B2 and B3 subsequently, see Figure 1. No cargoes are loaded in ports within region B.

An economic criterion used is the number of container restows. Restowing a container is an action of discharging or moving a container at a port to provide an access for other containers, in order to obtain a desirable stowage plans. Restows involve the usage of cargo handling resources consisting cranes and stevedoring personnel, which are costly.

A stowage planning session is a problem-solving session. The more plans one has created, the more capable he is to solve a planning problem. A learning aspect is viewed as a process of accumulating the knowledge of how to solve problems. This is done in the model by storing every stowage planning session into a database, from which past similar planning sessions can be retrieved.

A stowage planning task starts with a Container Loading List (CLL) received from the Sales Department. It contains information on the number of containers to be loaded at a port of loading, and to be discharged at a port of destination, see Figure 2.

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The content of the casebase is compared with the CLL. A trapezoidal fuzzy membership function is used to measure the similarity. It is now the planner's turn to decide if he intends to use a similar plan for solving his current task. Otherwise he create the plan from scratch.
The plan chosen to be used as a basis for creating the plan is called a basic plan. Solving the problem is conducted through copying the concept of the basic plan into the new plan. It usually needs some modifications before the planner arrives at the final plan.

A newly generated plan can immediately be used for solving new problems. This part represents an automatic learning mechanism. The algorithm is a predecessor of the Casestow.

Table 1: Planning Evaluation

<table>
<thead>
<tr>
<th>Case #</th>
<th>Basic Plan #</th>
<th>Ctrs removed</th>
<th>Ctrs added</th>
<th>Total modif.</th>
<th>Total ctrs</th>
<th>% modif.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>9</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>56</td>
<td>14.2</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>68</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>11</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>57</td>
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<td>4</td>
<td>0</td>
<td>4</td>
<td>52</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Table 1 shows the evaluation result of planning sessions originally using seven cases and seven new problems. An average 92% of containers have correctly been planned. The remaining 8% are subject to modifications in order to arrive at the final stowage plan. In other words, we only have to care about a small number of containers, after having obtained the basic plan, in order to generate a complete stowage plan.

3.2. Model 2

A second model is developed in order to demonstrate the mechanism of chained process of planning, see Figure 3. The ship is set to sail two regions, each consists of three ports of loading, 11, 12, 13 and 21, 22, 23 respectively. The planning process is manual. From plan 4-2-21 the planner originally produces plan 4-2-22. The first code points to the voyage number, the second to the plan number and the last points to the port code. If he finds that this plan is not feasible, then he may produce one or more plan variants, e.g. 4-4-23 and 4-6-23, see Figure 4.

Planning is not a unique problem solving task. For any single problem, more than one solutions of equal quality are possible. This conforms the fact in shipping practice. Even, two planners often produce two different plans for the same problem.

The above possesses some consequences. For every session there can more than one plans of equal quality available. Every stowage plan affects all plans to be generated at ports of loading to be called. Five other plans can be derived from plan 4-2-21. When it comes to plan 5-2-13, it is viewed no longer viable to continue this planning concept. Similar portrait is shown by plan 4-4-23 and its derivations.

A capability to foresee few events in next voyages is quite helpful to generate stowage plans efficiently. This involves a.o. weather effects on stowage and seasonal CLL.

4. Lessons Learned

4.1. Model 1

Information on the number of containers to be loaded (CLL) changes continuously. Traffic jam, accidents, production problems at factory and warehouse affect the arrival time of containers at port. In ports where the closing time is not applicable, a container is allowed to enter the terminal area without time restriction, the degree of certainty that a stowage plan is made according to the desired plan is relatively low. Heavy containers supposed to be stowed in deep in hold may come late; as a consequence these containers must either be stowed on deck or cancelled. It is not always easy to predict, which containers are a potential source of problem. The knowledge involving various operational aspects of container handling is very limited. A rigid IF-THEN formulation is not adequate to describe and address the situation.
For planners, it means a pressure. He must take the actual situations into current planning task. He must modify it slightly or rigorously or even he has to make a completely new stowage plan. He has to accomplish it quickly, as the ship is in the process of discharging and/or loading.

For a very limited number of voyages, a degree of resemblance among planning problems is evident. The more voyages made, a richer collection of planning problems are available. The chance for finding a higher degree of resemblance is higher.

In the early voyages, planning problems are entirely new. These are in case when a ship is planned to serve a new route or a newly built ship is to be put in service. In such a situation, the planner must solve a planning problem from scratch.

When one faces a similar problem, and he has solved satisfactorily, he tends to repeat this successful experience. A similar problem tends to have a similar problem.

This is foundationally an important hint towards determining the direction of desirable methodology for stowage planning automation. Problem solving is an act of copying successful similar planning session. This process is fast.

This foundational principle has a drawback. Not all types of problems can be solved using this principle, namely planning tasks for a ship set to serve a new route. This type of planning task is a minority of the planning tasks.

Model 1 showed the usefulness of applying the principle of ‘copying successful a similar planning session’.

### 4.2. Model 2

A route of a container ship in liner service may involve two or more ports. Stowage plan made for a particular loading port, will have direct consequences to the following loading ports. An excellent stowage plan for a particular loading port, may produce costly consequences for next ports. The objective of stowage planning is therefore to achieve a set of good stowage plans for all ports of call.

Planning is a process. Its quality will be seen after the process is finished. For a particular planning problem,

![Figure 5: Data Hierarchy](image)

there are more than one solution of equal quality. That means a planning task does not produce a unique solution.

To put the above in the frame of stowage planning for a container liner shipping, the process of planning is a chained process. Costly consequences of a poor plan for a particular loading port can be seen after generating few stowage plans.

These consequences are costly. Therefore the capability to oversee overall planning situations of all ports of loading is important to conduct effective stowage planning tasks.
5. Desirable Qualities of Future Stowage Planning Tools

Defining desirable qualities of stowage planning tools involves the understanding on the requirements of reality in container shipping, namely how acceptable or relatively good stowage plans can be obtained quickly.

We view it is unrealistic to set an objective to build a machine or a tool which can provide us a finished stowage plan. Stowage planning involves subjective aspects (certain types of cargoes or certain clients' cargoes) which are hardly possible to formulate consistently and completely. A user still wants control on the process of planning. A planning tool therefore must provide a room for intervention of the user. It is desirable if a tool is error-free. A human planner may find it less dramatic, if the produced stowage plan is not entirely correct or even erroneous. But he would find it annoying if the tool consistently produces errors; especially when the tool repeats same mistakes. He might expect, that the tool should be more intelligent; it might not repeat the very same mistake. For this, the tool must have the capability to learn.

A planning task starts when the number of containers to be loaded (CLL) and the arrival conditions of ship are known. CLL changes over time. In practice, even when loading and discharging have been taking place, CLL might still change. A slight change of CLL, would produce a slight change in the stowage plan. Every time a planner assesses the situation when he should replan.

Furthermore, planning involves also a growing degree of details of the information. Early information contains merely the number of containers. Later on, as the loading date gets closer, the contents of container become known, see Figure 5. When the container contains dangerous cargoes, or certain types of cargoes which might affect their quality (such as tobacco and rice), the planner should replan.

A future automatic stowage planning tool should possess the following properties:

a. assistance to the planner by providing a half-finished solution, instead of 'taking over' the planner by providing a fully finished solution: due to subjective preferences.

b. capability of coping with changes: as planning conditions (geographical restrictions, port infrastructure, trading patterns, cargo owners' preferences) change over time.

c. learning capability: it is unacceptable, if the method produces the same erroneous outputs for the very same input. The method should ideally become smarter.

The Case-Based Reasoning (CBR) methodology used in the Case-Based Stowage Planning System (Casestow) [1,2,3] is proposed to address the above. CBR solves a new problem, through reusing the idea how similar problems in the past were solved [8]. A task to create a plan is called a problem. When a planner receives a planning problem, he would recall similar problems known.

Every planning session contains knowledge on how a planning problem was solved. Its quality may vary from poor till favourable ones. All those experiences are valuable. One tends to repeat a favourable one, and to avoid a poor one. The key is to organize the planning experiences in such a way so that retrieving and reusing past planning sessions are enabled.

The procedure of Casestow is shown in Figure 6. The task is to draw a stowage plan of a port of loading (POL). The input consists of two elements: the arrival conditions of the ship and the container loading list (CLL).

\[
\text{problem} = \langle \text{arrival stowage plan prior to loading, container loading list} \rangle
\]

\[
\text{solution} = \langle \text{departure stowage plan} \rangle
\]

\[
\text{remark} = \langle \text{quality or comments on the plan} \rangle
\]
A case is defined as a completed planning session consisting of a problem, its solution and its remark. The actual stowage planning task is called query consisting only one element: the actual problem. Casebase is where those cases are stored.

\[
\text{case} = \langle \text{stored problem, stored solution, stored remark} \rangle \\
\text{query} = \langle \text{actual problem} \rangle
\]

A planning session begins by comparing the query with problems stored in the casebase. The degree of similarity between the query and stored problems is then calculated. There are two types of data to be compared: numerical (CLL) and graphical data (stowage plan). The numerical similarity value is computed using a trapezoidal fuzzy membership function, as the values of the actual problem are viewed as an approximation.

6. Conclusion

Determining methodological directions for automating the process of planning found its roots in the Wittgenstein's picture theory of meaning, where desirable qualities of a plan cannot be determined precisely and consistently.

Two models are an attempt to raise our insights on planning. The models show few important notions of planning principles:

a. planning is a problem-solving task, which has often more than one equally feasible solutions.

b. capability & speed of performing planning task improves in line with the degree of resemblance of current task to previous known tasks.

The above have led to applying the Case-Based Reasoning for the Casestow.

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References


