

The Application of Fuzzy Expert System to Preliminary Development Planning  
of Medium Size Container Terminal

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## ABSTRACT

The aim of this study is to develop a fuzzy expert system to serve as an alternative to the conventional method of container terminal development planning. The conventional method commonly used by port planners in developing countries employs planning charts and empirical formulas. It requires precise inputs although these values are forecasted and imprecise. It is short of component which allows planning under uncertainty. Hence, there is a real need to improve the current method so that port planners in developing countries can apply their natural modes of reasoning that involves approximate, imprecise, linguistic and subjective values. The study has proposed an enhanced model of container terminal development planning. It has applied triangular membership functions concept and centre of gravity method for the fuzzification and defuzzification processes respectively. Fuzzy Associative Memory (FAM) method has been used to derive rules for the CLIPS (C Language Integrated Production System) expert system database. The system developed has been verified against the conventional method to confirm its accuracy and a case study has been performed to prove its practical usability. Data extraction and expert knowledge generation involving fuzzification and defuzzification processes has been done accurately. The Pearson r-squared analysis performed on the correlation lines did not show any inconsistency in quality. More than three quarter of the rules used represent genuine expert knowledge while the rest are rules that store default values. The verification results show that the system is accurate and no indication of inefficiency from the use of forward chaining CLIPS. The case study proves that the expert system database is complete and all unexpected results are traceable to the inappropriate combination of planner inputs. Therefore, the study has successfully developed an accurate and efficient fuzzy expert system which can serve as an alternative tool for container terminal development planning and solves the problem of lack of human modes of reasoning found in the conventional methods.

## ABSTRAK

Tujuan kajian ini ialah untuk membangunkan sebuah sistem pintar fuji sebagai alternatif kepada kaedah konvensional perancangan pembangunan terminal kontena. Kaedah konvensional yang biasa digunakan oleh perancang-perancang pelabuhan di negara-negara membangun menggunakan carta-carta dan formula-formula empirika. Ia memerlukan input yang tepat walaupun nilai-nilai ini adalah ramalan dan tidak tepat. Ia tidak mempunyai komponen yang membolehkan perancangan dalam ketidakpastian. Dengan itu terdapat keperluan untuk memperbaiki kaedah-kaedah sekarang supaya perancang-perancang di negara-negara membangun boleh mengaplikasikan mod penghujahan tabii mereka yang melibatkan anggaran, ketidaktepatan, linguistik dan nilai-nilai subjektif. Kajian ini telah mencadangkan sebuah model perancangan terminal kontena yang dipertingkatkan. Ia telah menggunakan konsep fungsi keanggotaan segitiga dan kaedah pusat graviti untuk proses-proses fuzifikasi dan defuzifikasi masing-masing. Kaedah Fuzzy Associative Memory (FAM) telah digunakan untuk menghasilkan aturan-aturan bagi pengkalan data sistem pakar CLIPS (C Language Integrated Production System). Sistem yang dibangunkan telah disahkan berbanding kaedah konvensional untuk pengesahan ketepatannya dan kajian kes telah dilaksanakan untuk membuktikan kebergunaan praktiknya. Pengambilan data dan penghasilan pengetahuan pakar yang melibatkan proses-proses fuzifikasi dan defuzifikasi telah dilakukan dengan tepat. Analisis Pearson r-squared yang dilakukan pada garisan-garisan korelasi tidak menunjukkan ketidakkonsistenan kualiti. Lebih dari tiga perempat aturan yang digunakan mewakili pengetahuan pakar yang asli manakala selebihnya adalah aturan-aturan yang menyimpan nilai-nilai lalai. Keputusan pengesahan menunjukkan bahawa tiada tanda-tanda ketidakcekapan dari penggunaan CLIPS kaedah perantaraan ke depan. Kajian kes membuktikan bahawa pengkalan data sistem pakar adalah lengkap dan semua keputusan luar jangkaan yang diperolehi dapat dikesan berasal dari kombinasi input perancangan yang tidak bersesuaian. Dengan itu kajian ini telah berjaya membangunkan sistem pakar fuji yang tepat dan cekap yang boleh berfungsi sebagai alat alternatif untuk perancangan pembangunan terminal kontena dan menyelesaikan masalah ketiadaan mod penghujahan manusia yang terdapat di dalam kaedah konvensional.

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## LIST OF SYMBOLS

$<<$	FAM value below UNCTAD (1985) range
$>>$	FAM value above UNVTAD (1985) range
$abdr$	Annual berth-day requirement
$abdr$	Annual berth-day requirement
$abtps$	Average berth time per ship
$acs$	Annual ship's cost at terminal
$adsc$	Average daily ship cost
$a_i$	The $a$ value of the triangular fuzzy number (a b c)
$anmps$	Average number of movement per ship
$anuphpc$	Average number of unit per hour per crane
$arpt$	Area requirement per TEU
$ashogc$	Average stacking height of general cargo
$att$	Average transit time
$bdr$	Berth-day requirement
$bdrpb$	Berth-day requirement per berth
$b_i$	The $b$ value of the triangular fuzzy number (a b c)
$bu$	Berth utilisation
$cdpy$	Commission days per tear
$cfs$	Container freight station
$cfsaf$	Container freight station's access factor
$cfsasa$	Container freight station's average storage area
$cfsatt$	Container freight station's average transit time
$cfscmpy$	Container freight station's container movement per year
$cfsdsa$	Container freight station's design storage area

<i>cfshc</i>	Holding capacity of container freight station
<i>cfsrcsf</i>	Container freight station's reserve capacity safety factor
<i>cfssa</i>	Container freight station's storage area
<i>chs</i>	Container handling system
$c_i$	The $c$ value of the triangular fuzzy number (a b c)
CLIPS	C Language Integrated Production System
<i>cmpy</i>	Container movement per year
<i>cpa</i>	Container park area
<i>er</i>	Equipment rating
F	Value after the application of interest rate
<i>fsi</i>	Fuzzy suitability index
<i>gtsar</i>	Gross transit storage area
<i>H</i>	High
<i>hcr</i>	Holding capacity required
<i>i</i>	Interest rate
<i>L</i>	Low
<i>M</i>	Medium
<i>MH</i>	Medium high
<i>ML</i>	Medium low
<i>n</i>	Number of year
<i>ncps</i>	Number of crane per ship
<i>nob</i>	Number of berth
<i>nspy</i>	Number of ship per year
<i>ntsar</i>	Net transit storage area
<i>nupdpb</i>	Number of units per day per berth
<i>nupdpc</i>	Number of units per day per crane
P	Initial investment value
<i>possoomastiq</i>	Probability of ship having to wait for service for a period equal to the length of an average service time
<i>rcsf</i>	Reserve capacity safety factor
<i>roatmsh</i>	Ratio of average to maximum stacking height
<i>sc</i>	Selection criteria
<i>sc<sub>l</sub></i>	Land use

$sc_2$	Terminal development cost
$sc_3$	Equipment purchase cost
$sc_4$	Equipment maintenance factor
$sc_5$	Manning requirement
$sc_6$	Operating factor
$sct$	Ship cost at terminal
$ssohpd$	Standard ship operating hour per day
$toapb$	Terminal's other area per berth
$tochs_1$	Trailer-chassis system
$tochs_2$	Straddle carrier direct system
$tochs_3$	Straddle carrier relay system
$tochs_4$	Yard gantry crane
$tochs_5$	Front-end loader
$tochs_6$	Combination system
$tochs_{ranked}$	Fuzzy suitability index ranked using Chen (1985) method
$tstap$	Total ship's time at terminal
UNCTAD	United Nation Convention on Trade and Development
VH	Very high
VL	Very low
VVH	Very very high
VVL	Very very low
$woi$	Weight of importance
$X_{max}$	Maximum $fsi_c$ value from all $tochs$
$x_{min}$	Minimum $fsi_a$ value from all $tochs$

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Research Objective**

The objective of this research is to develop a fuzzy expert system for the preliminary development planning of a medium size container terminal.

#### **1.2 Research Background**

##### **1.2.1 Basic definitions on container terminal development planning**

A seaport consists of many functional components. Cargo of various categories (dry and liquid bulk, break bulk, etc) are received, stored and shipped via its terminals. Consequently, terminals are classified according to the type of cargo being handled. Thus, container terminals process containerized cargo only. A port or

a terminal is said to be ‘multi-purpose’ when it handles various categories of cargo. A container port is a specialized port since it handles containerized cargo only.

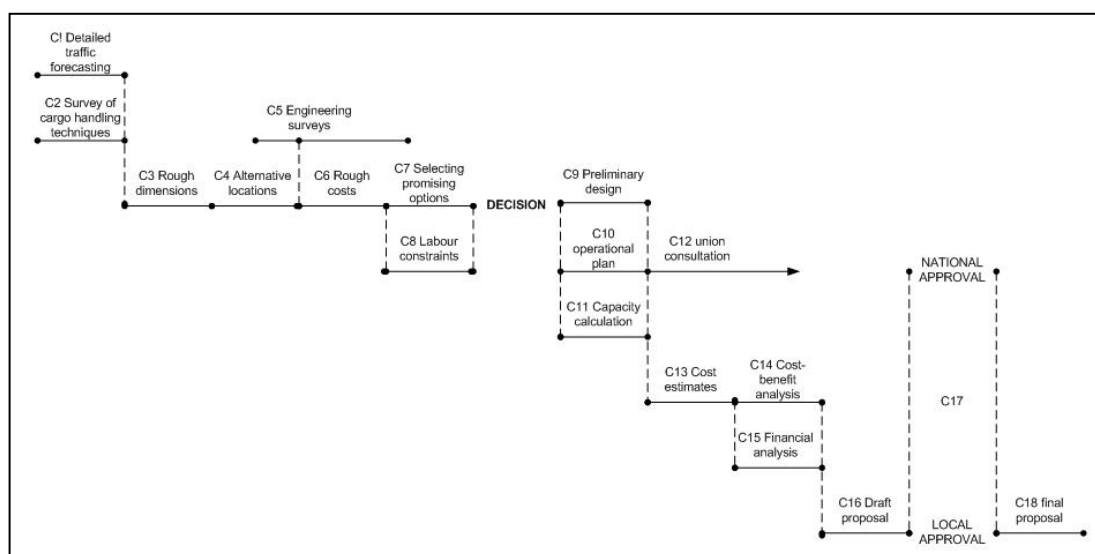


Figure 1.1: A full spectrum of port development planning (Source: UNCTAD; 1985)

Mettam (1998) provides a good clue as to what constitute a plan. It says that, generally, some planning studies are restricted to engineering and economic aspects of development. Others may involve management and financial appraisal. A more detailed plan focuses on a single aspect such as operational efficiency. Figure 1.1 shows the full spectrum of port or terminal development planning studies. Hence, it can be safely deduced that there is no fixed list of what should be the sub-components of a container terminal development plan. The various sub-components are included to serve the differing purposes.

Standard literatures on the subject normally include container terminal planning under the bigger subject of port planning. Frankel (1987) defines port and terminal design as involving ‘...a number of distinct steps such as port requirements determination and existing capacity evaluation, all leading to the actual port and terminal design’. Within the larger study container terminal development planning appears as one subset of port development planning (other subsets includes general



cargo terminal planning, multi-purpose terminal planning, etc). As such, container terminal development planning only covers specific aspects.

UNCTAD's (1985) Port Development Handbook provides the best evidence of what constitute a container terminal development planning. Terminal design principles involve '...methods of calculating the required capacity of a terminal to handle a given traffic demand'. It starts with the number of TEU (twenty foot equivalent units) planned for, followed by selection of facilities and ends with checks on the acceptability of the plan in term of ship's cost at the terminal. Therefore a container terminal plan primarily lays down features describing space requirement and equipment selection. All other aspects such as nautical (channel width, depth and layout), civil engineering and environmental and safety are detailed planning.

### **1.2.2 General nature of container terminal development planning.**

The objective of port, hence, container terminal development planning is 'to provide port facilities and operating systems in the national interest at the lowest combined cost to the port and the port users' (UNCTAD, 1985). UNCTAD (1985) suggests that in its traditional form, container terminal development planning 'demands a good knowledge of the future customers and their probable cargoes. It is a challenging and complex task that requires a good deal of common sense and a certain talent and creativity for visualizing the future. There is no substitute for experience and sound judgement'. Traditional container terminal development planning is simply an art.

However, planning methods have changed. Mettam (1988) detected that since 1960s planning techniques have been developed so that many disciplines were used and coordinated to give an integrated approach in planning. Likewise, container

terminal development planning has evolved from being an art to more of a science. Currently it still possesses the qualities of both art and science.

Frankel (1987) summarises the qualities that describe it as a process comprising of distinct steps and the whole process is part of a design spiral that requires input data, performs calculation and produces outputs. The following highlights those qualities:

- a) Firstly, planning is a process. It draws a particular course of action and performs mathematical and logical operations on data according to programmed instructions in order to obtain the required results (Hyper Dictionary, 2003). Steps within the process are perfectly established such that they are distinct.
- b) Secondly the process is part of a design cycle and hence an iteration. It means that the required results could be improved by repeating the process for a number of cycles.
- c) Thirdly, it involves input data that could be quantitative as well as qualitative. Some planning data appears to be exact values such as the number of ship arrival per year. Others are issues that are complex and inexact such as constraint on manning level and land utilization.
- d) Fourthly, therefore, exact data is processed mathematically while inexact inputs are qualitatively evaluated.

As far as planning execution is concerned, two common methods are obvious. One is where formulas describing the many elements of a plan are presented as their original mathematical terms. Each formula will bind together more than one planning variables. The other is by graphical plots (or planning charts) where curves are drawn to represent the correlation between variables. Thus planning element may be derived from one or more plots. To use both concepts port planners are required to furnish the values of the unknown variables. It is worth noting that Frankel (1987) uses the first concept while UNCTAD (1985) uses the second. UNCTAD simplifies it into planning charts with the perception that it would be

better for port planners in developing countries that lack skill and information in planning.

The following characteristics describe the difficulties associated with quantitative and qualitative planning methods:

- a) Mathematical programming methods need crisp data in order to get meaningful results. This need stands in sharp contrast to the high level of uncertainty associated with container terminal development planning. Usually decision makers refrain from such techniques (Evineri, 2000).
- b) Some crisp values are fluctuating values. For example, the number of ship arrivals per year is statistically derived from data collected over many years. There are some degrees of uncertainty in statistical works. Uncertainty is further amplified when projection is made by extrapolation methods.
- c) Inexact data are measured in incommensurable units and there is the lack of consensus regarding values of measures.
- d) Qualitative evaluation of inexact values is influenced by port planners' own opinions. For example, the process cannot avoid dealing with issues of multiple connecting objectives. There is varied consensus on the degree of influence of each qualitative input. Inconsistency is also possible on the possible mix of inexact values. Both influence the final results.

With regards to these characteristics, container terminal development planning relies on expert knowledge. However, as claimed by Klir et. al (1997), such knowledge is always ill-defined and heuristic. It can usually be expressed in an uncertain way. Hence, results from planning methodologies that are able to effectively represent and manage such uncertainty should be better. Preference towards approximation in container terminal development planning has been indicated in Thomas's (1999) work when he introduced the idea on the selection of container handling system selection. However, he has not provided enough detail. The introduction of fuzzy methods to planning methodologies is aimed at this very purpose.

### **1.2.3 Current focus of computer applications in container terminal development planning.**

As in other domains, computer is applied to port and container terminal development planning to perform repetitive tasks such as storage and retrieval and manipulation of data, basic calculations and comparison of results. For such functions, computer works with a speed and accuracy that could never be matched by human. Furthermore, computer capacity has expanded faster than any volume of task that human can imagine. Port planners and programmers alone are the limit to computer application in planning works.

Early application is of course in the form of conventional software. It adopts the waterfall concept of programming where input data are exact and functional. When science has successfully developed methods to systematically apprehend the heuristic, interactive and flexible parts of planning, it shifts towards a form known as ‘expert system’. The name reflects its similarity with the thought process of a human expert (Yen and Davis, 1999). It is a reasoning system that performs at a level comparable to or better than a human expert does within a specified domain (Horvitz et al, 1998).

Expert system is one of the five common tools of artificial intelligence (other tools include fuzzy logic, inductive learning, neural networks and genetic algorithms). It is a computer program that embodies knowledge about a narrow domain for solving problems related to that domain (Pham and Pham, 1999). It is a program that has a wide base of knowledge (hence the reason for being named knowledge-based systems) that uses complex inferential reasoning to perform tasks that a human expert could do (Metaxiotis et. al, 2002).

Expert system uses strings of information (knowledge) rather than exact and functional data. The information is stored in the ‘knowledge base’ in the form of a

set of ‘rules’ (facts and heuristic) learned from experts in the domain. When users interact with the system through its ‘dialog box’, the ‘inference engine’ matches the user input against the rules. Matching rules are fired and served as the system’s output for that particular user input.

Liebowitz (1995) believes that expert systems are probably the most practical application in the field of artificial intelligence. They have emerged as useful, deployable systems that are being operationally used worldwide. Expert System has been applied to virtually all areas (Bresina, 1999) of decision making including (i) interpretation, (ii) diagnosis, (iii) monitoring, (iv) prediction (v) planning, and (vi) design. In the neural-expert system field Wong et. al. (1997) detailed the areas of application to include (i) accounting/auditing, (ii) finance, (iii) human resource, (iv) information system, (v) marketing/distribution, and (vi) production/operation.

Presently, researchers, port planners and programmers focus more on creating simulation system for container terminal operations. The lack of expert system’s application in planning is also noticed by Han et al. (1989). Han hypothesizes that the reasons could be due to experts not agreeing to solutions, cost effectiveness in relation with the vast amount of expert knowledge, technical and theoretical limitations and problem in integrating the many subcomponents of planning.

A quick survey made has shown (Table 1.1) that system studies for container terminal development highlight their strength on this aspect. It is quite naturally so due to demand factors. One reason is probably due to only few new terminals or expansion works being planned yearly. More terminal operation tools are required to improve current operating performance as compared to those for development planning.

Table 1.1: Research focus on container terminal planning

MODEL/SOFTWARE & THEIR USE	AUTHOR
Total container terminal operation management	Gambardella et. al (2001)
Storage, resource allocation, scheduling and coordination	Bontempi et. al (1997), Gambardella et. al (1998), Henesey et. al (2002)
Container loading and unloading operation	Mastrolili (1998), Duinkerken (2000)
Quay-to-yard container transport	Bose et. al (2000)
Container stacking	Duinkerken et. al (2001)
Sequencing of equipment and manpower over work shifts	Zaffalon et. al (1998)

On one side of the balance, demand factors have driven container terminal operations software packages to be very specialized and sophisticated. Specialisation intends to make each system smaller and thus cheaper while sophistication intends to provide a marginal competitive advantage to the provider. On the other side, packages for container terminal development terminal planning are even hard to find. However, that does not make container terminal development planning packages unimportant. It is obvious that a good terminal starts with a good initial planning.

There are arguments that suggest the use of operational performance packages for terminal development planning. But that is only a lame marketing gimmick since such a solution inherits two main problems. Firstly, operational performance simulation packages are too specialized that integrating their results into a total planning perspective can be quite an impossible task. Secondly, port planners will be overburden with input data for variables not at all required in basic planning. This will lead to unnecessary cost and delays.

#### 1.2.4 Fuzzy logic in expert systems

Fuzzy set theory was introduced by Zadeh (Deb et. al, 2002) to deal with problems in which there are data ambiguity and impreciseness. It employs approximate, rather than exact, modes of reasoning, and therefore incorporates imprecise, linguistic and subjective values. Using the theory, all planning variables that are subjected to impreciseness are represented by linguistic (cognitive) terms. These terms in effect represent all possible values for the variables. Therefore, each term is a partition of the values expressed in terms of its membership to the mathematical function representing the values. Hence, port planners will insert planning inputs in cognitive form rather than exact values.

Fuzzy set theory is a convenient and flexible tool for dealing with linguistic description (Avineri, 2000). It is recognized as an excellent tool for dealing with uncertainty regarding each data, its combination and drawing of inference (Yen and Davis, 1999). It is preferred because of its proven ability as a universal approximation that has power and analytical depth (Chen et. al, 1999). The use of fuzzy logic in expert systems intends to make the systems more flexible. “It intends to solve problems not covered explicitly in their knowledge bases (that is, situations not fitting exactly those described in the ‘IF’ parts of the rules)” (Metaxiotis et. al, 2002). Knowledge in an expert system employing fuzzy logic is expressed as qualitative statements. Fuzzy expert systems are more frequently used because of its simplicity and similarity to human reasoning (Hong et. al, 1996). Raj and Kumar (1999), on quite a similar issue, argues that fuzzy set theory is preferable because it is intuitive, simple and straightforward and easy to implement.

### 1.3 Problem Statements

From the preceding paragraphs it is evident that current tools for basic container terminal development planning have suffered due to wrong simplification attitude. Two reasons prevail; one purposeful while the other is circumstantial. On the one hand it has been made simple to cater for the assumed lack of skill and planning information on the part of the users. This has been clearly stated by UNCTAD (1985). On the other hand system developers refuse to understand that basic planning and operational performance packages, despite being related, requires two different degree of attention as far as simplification and sophistication are concerned.

Both have taken its toll. Over simplification by UNCTAD by making it totally quantitative has constrained port planners from applying their natural (human) mode of thinking in planning. Quantitative style of container terminal development planning rejects approximation and ambiguity that characterise human reasoning and decision making. Over simplification attitude by system developers has denied treatments of basic container terminal development with its own right of sophistication. Thomas's (1999) idea of using approximation in the selection of container handling system probably intended to solve this problem.

The present work proceeds with a research statement that the present over simplified container terminal development planning approach should be improved with such a sophistication that suffice it purpose. It is worth highlighting that the present research is closely similar to the doctorate research work by Mainal (1993). He developed an expert system for the design of an offshore supply vessel. Traditionally, offshore supply vessel design process adopts a waterfall approach similar to UNCTAD's container terminal development planning approach. Mainal's core contribution is on the incorporation optimisation sequence and uncertainty measures to the sets of mathematical formulas established by others.



## **1.4 Scope of Research**

The present research proposes an alternative container terminal development planning methodology using fuzzy expert system approach. Towards achieving this objective, the most direct approach has been adopted. Topics are covered when they have direct material contribution towards the research objective. Depth of coverage is given according to their relevance. In arguing its cases, the research hinges more on supporting facts and findings from research works performed by others rather than through its own comparative studies. This will avoid reinventing the ‘wheel’.

Hence, the build up stage (literature studies), the intermediate stage (development of research methodology) and the closing stage (results and discussion) of the research focus only on three principal topics:

- ✓ container terminal development planning process and modelling,
- ✓ fuzzy set theory and development of knowledge base
- ✓ development of expert system source code and verification of results.

A case study has been included to simply demonstrate that the expert system is operationally deployable in the real world.

## **1.5 Structure of Dissertation**

This dissertation has been divided into six chapters. Each chapter has been partitioned into few parts while each part can have its own sections. Sectioning and partitioning have been carefully done so that their content and positioning complement the flow of dissertation as a whole.

Chapter 1, the present chapter, is on the general introduction to the research. It contains five parts and as follows.

**Part 1** specifies the objective of the research which ultimately set the course of the study.

**Part 2** introduces the research by (i) defining the term “container terminal development planning” within the context of this research. A proper definition is required so as to show the many elements it contains, all of which are part of a process; (ii) describing the nature of container terminal development planning to show that it is a decision making process, partly art and partly science, that is hampered by ambiguity and impreciseness; (iii) introducing the role of fuzzy method in addressing ambiguity and impreciseness and its advantages as claimed by other researchers; (iv) introducing the application of computer and expert system in the field of container terminal development planning to show the current research emphasis and focus.

**Part 3** describes the problem statement of the research, specifying the current real world problem that the research intends to solve.

**Part 4** describes the scope of the research, specifying the boundary of approach and coverage inline with the set objective.

**Part 5** describes the structure of the dissertation.

Chapter 2 is on literature studies that review all topics which are important to the reasoning used in the design of the research methodology. It contains three parts and as below.

**Part 1** summarises (i) the container terminal development planning models developed by UNCTAD (1985) and Frankel (1987) to indicate their important components; (ii) Thomas’s (1999) guidelines for the selection of types of container handling equipment; (iii) Schonfeld and Sharafeldien’s (1985) guidelines on the number of crane per berth.

**Part 2** summarises the relevant theories on (i) fuzzy set, fuzzy numbers and the use of linguistic variables in fuzzy methods; (ii) shapes of membership function and suggestions on the process of assigning and

partitioning membership function; (iii) algebraic operation involving fuzzy numbers; (iv) aggregation of fuzzy numbers, and (v) ranking of fuzzy numbers.

**Part 3** summarises the relevant knowledge on expert system including (i) description of an expert system architecture; (ii) rule-based expert system; (iii) forward chaining and backward chaining; (iv) developing rules using the Fuzzy Associative Memory method; (v) criteria for the selection of expert system shell; and (vi) strategies for the validation, testing and evaluation of expert system.

Chapter 3 details the design of the research. It covers all methods used and activities performed towards achieving the required results. These have been arranged as below.

**Part 1& 2** details (i) the container terminal planning model developed for this research and the reasoning employed towards developing it, (ii).the meanings of decision variables used and their correlations, and (iii) the steps and their sequence along the planning process.

**Part 3** describes the flowcharts of the expert system developed. It explains the overall structure of the system as well as the details structure for each of the calculation modules.

**Part 4** describes the methods employed in extracting information from UNCTAD's planning chart. It includes deriving mathematical equations for each line in UNCTAD's planning chart and deriving additional lines; intermediate (lines between UNCTAD's original lines) and extrapolated. Additional lines have been derived base on plot of gradient and involve linerisation. The above has been used to convert UNCTAD's data for container park area, container freight station area, berth-day requirement and ship cost at terminal.

**Part 5** explains why the triangular method of deducing membership functions has been applied to variables used for the planning model. It also explains the strategy adopted in deriving the membership functions of the data used.

**Part 6** explains the modus operandi of deriving the rules for the expert system. Fuzzy Associative Memory method has been used and all fuzzy operations including defuzzification by centre of gravity method have been clearly shown.

**Part 7:** presents the algorithms used to determine the type of container handling system for the terminal.

**Part 8** illustrates the style used in writing the source codes. It explains the build up of the codes for one single rule, organising facts, organising files in one large module and tricks codes for resetting the programs.

**Part 9** contains details on the method of verifying outputs from the expert system and the case study carried out. Output verification is aimed at checking whether the knowledge base has been accurately developed. On the other hand, the case study is aimed at detecting unexpected results such as when planning horizons are surpassed.

Chapter 4 discusses the results of the study. It contains three groups of results as follows:

**Part 1** presents the results from the general observation made during the methodological part of the study. Three important general observations have been recorded. First is on the shapes of trend lines generated using Microsoft Excel when UNCTAD's planning data are converted into mathematical forms. An overall comment has been given based on visual inspection of each trend line and checking on the Pearson- $r^2$  value of the trend line that is detected to be problematic. Second is on the chances of encountering interruption while using the expert system when planning limits are surpassed. The chances have been calculated based on the number of 'IF-THEN' rules that return a 'no result' each time a planning limit is exceeded. Third is on the membership value associated with each of the rules derived using the Fuzzy Associative Memory (FAM) method. The membership value shows the degree to which the calculated defuzzified value calculated belong to the fuzzy set.

**Part 2** presents the results obtained from the verification exercise performed on the expert system's output. Outputs from all modules that only require UNCTAD's planning data, namely container park area module, freight station area module, berth-day-requirement module and ship cost at terminal module, have been analysed at selected user linguistic inputs. A special method of measuring accuracy has been proposed for the exercise where the main target is to determine whether the expert system's output could encompass the output obtained when UNCTAD's original planning charts are used.

**Part 3** presents all results generated when the expert system is put into practical use during the case study. Data from Johor Port Sdn. Bhd. has been gathered and fed into the expert system. Efforts have been focused on showing the smooth running of the system including the validity of the planning data used to generate the 'IF-THEN' rules.

Chapter 5 discusses the results obtained from the study. The discussion is grouped in accordance with the grouping used in Chapter 4 and as follows:

**Part 1** discusses the results presented earlier as general observations in Chapter 4. It discusses specifically on the existence, reasons and possible remedies of inaccuracy on trend lines and on the chances of interruption to users when planning limits are exceeded. It assesses the severity of the problems and gives judgement on the importance of the proposed remedial actions.

**Part 2** discusses the results from the verification exercise performed on the expert system. It focuses on the existence of results which show a mismatch between the expert system's output and the output from UNCTAD's planning charts. It detects the accuracy of the expert system, highlighting their pattern and predictability and determines how such inaccuracy could occur.

**Part 3** discusses the results obtained from the case study. It discusses the two most important deductions seek for from the case study; (i) accuracy of the expert system and (ii) ability of the expert system to handle extreme inputs.

Chapter 6 forwards the conclusions of the study. It starts by highlighting the motive of the study and the methodology that has been selected. Five conclusions are then forwarded to show the successfulness of the research. The chapter closes with four recommendations for the possible continuation of the research.

## **1.6 Summary**

UNCTAD (1985) and Frankel (1987) define container terminal planning as involving the determination of port requirements and capacity calculation to handle a given traffic demand. It requires common sense, talent, creativity, experience and sound judgement. However, the commonly used conventional methods of container terminal planning designed by UNCTAD (1985) and Frankel (1987) that quality of human mode of reasoning. UNCTAD's (1985) method uses planning charts while Frankel's (1987) method uses empirical formulas, both requiring crisp input values. Thomas (1999) suggested that container terminal planning would be better done by approximation method.

Yen and Davis (1999) mentioned that expert system reflects its similarity with the thought process of a human expert and Hovitz (1998) said that it is a reasoning system that perform at a level better than a human expert does within a specific domain. Liebowitz (1995) earlier claims that expert systems are probably the most practical application in the field of artificial intelligence and Bresina (1999) confirms that it has been applied to virtually all areas of planning. According to Hong et. al (1999) and Raj and Kumar (1999) fuzzy expert system are more frequently used because it is intuitive, simple and straight forward and easy to implement.

Therefore, the objective of this research is to develop a fuzzy expert system for the preliminary development planning of a container terminal. The problem statement hinges on the argument that current planning methodologies lack human mode of reasoning that involves approximate, imprecise and subjective values. Towards achieving this objective this research focuses on three principal scopes of work. First is modelling the components and processes of container terminal development planning. Second is developing knowledge base using fuzzy set theory. Third is developing the expert system source code and verification of results. This dissertation has been divided into six chapters. Chapter 1 is on general introduction to the research. Chapter 2 is on literature reviews of all topics which are important to the design of the research methodology and system development. Chapter 3 details the design of the research and the system developed. Chapter 4 presents the results obtained and Chapter 5 discusses the results. Chapter six concludes the research and proposes some recommendation for future works.

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