ELEN TWRDY, Ph.D.
E-mail: elen.twrdy@fpp.edu
University of Ljubljana,
Faculty of Maritime Studies and Transport
Pot pomorščakov 4, SI-6320 Portorož, Republic of Slovenia
BOJAN BEŠKOVNIK, M.Sc.
E-mail: bojan.beskovnik@intereuropa.si
Intereuropa, Globalni logistični servis, d. d.,
Vojkovo nabrežje 32, SI-6000 Koper, Republic of Slovenia

Traffic Planning
Review
Accepted: Nov. 16, 2007
Approved: Sep. 22, 2008

PLANNING AND DECISION-MAKING TO INCREASE PRODUCTIVITY ON A MARITIME CONTAINER TERMINAL

ABSTRACT

This article describes orientations in optimization of operations on a maritime container terminal. With the application of an adequate model for forecasting, planning and simulating it is possible to increase the productivity and optimize the capacity of the terminal. The emphasis is mainly on setting up the decision making model, in order to raise productivity in all subsystems of the maritime container terminal.

Management of a maritime container terminal is a complex process, which includes a vast number of different decisions. The management must develop elements and strategies for checking the productivity and its rise, which can only be achieved through optimization of the entire system. With knowledge about new technologies, operational processes, methods of forecast and simulation it is possible to achieve the easiest usage of different strategies for improving productivity. This is particularly valid for terminals, where the physical extension of the terminal is practically impossible and further development of the system is possible only by searching internal sources. Therefore, the management of a maritime container terminal must develop an appropriate decision support model, in order to make an adequate support to strategic decisions. These decisions relate basically to the assessment of the best development and optimization decisions and on application of proposed solutions in the infrastructure and suprastructure of the terminal.

KEY WORDS

Maritime container terminals, productivity, decision model, planning

1. INTRODUCTION

Generally terminal means the star or end point for goods in transit. The main function of a container terminal is to transfer containers safely, promptly and correctly between the different modes of transport - between main line of vessels and feeder vessels or road/railway transport vehicles. To obtain the advantages of mass transport the main line ships transport large number of containers. Feeder services as connecting services provide a medium number of containers. Total different situation is in the land side. Railways provide relatively small number of containers and road transport provides frequent pick-up/delivery for door to door service. In such situation it is very difficult to obtain the maximum of productivity of container terminal.

There are also big differences between the terminals in sense of technical equipment, the handling capacities and infrastructure. But they are all faced with more and more containers to be handled in short time and at a low cost. Therefore they are forced to enlarge capacities and to achieve gains in productivity. It is essential for operators to reduce unproductive time at the port and to offer effective processes in order to meet the increasing competition among terminals. High investments as well as high operating costs for ships and port equipments enforce improvements of terminal operations. A terminal's competitiveness includes issues of waterside operations and internal logistics as well as landside operations, transport connection and routing within the surrounding area. For meeting the needed current/future demand different concepts are utilized. First one is the design of new terminals with advanced layouts. Another approach is the replacement of older equipment with more efficient one. The last one is the use of existing infrastructure and equipment but more efficiently, e.g., by means of powerful information technology and logistics control software systems including optimization methods[1].

Therefore the management of maritime container terminals is a complex process, which requires a vast

number of different time limited decisions. Different simulation systems have been developed for decisions support, which enable operational supervision and are efficient support to key decisions. Notwithstanding programme tools give only partial processed data, which must be additionally adjusted and included in the real system. Information tools cannot replace simultaneous decisions (e.g. to work on vessel with three hands and not unload the train or to work with two hands and unload the train at the same time). Such decisions are always in the hands of terminal operators, who base their decisions on experience and present priority tasks. Simulation programs are often inflexible and it is difficult to adapt them to the real conditions as per subsystems, because working conditions continually change.

Regular productivity checking enables continuous work control of every single subsystem and working process on the terminal. This way, operators acquire needed data of activity and optimization possibilities of the system. One-sided analyzed and applicable decisions of increasing productivity and exploitation of subsystems can have indirect negative consequences on the work of other subsystems and elements of the system. Interests of every single subsystem are very often in conflict with each other (with increasing infrastructure occupancy the unloading productivity is decreasing, because it is more difficult to access containers, quick manipulation is impossible, and at the same time, the number of mistakes and damage on containers is increasing).

The owners or the management of a maritime container terminal must develop an adequate system of collecting and assessing work information about suprastructure and infrastructure occupancy, which is consecutively expressed with the production of the entire system.

2. SETTING UP A DECSION MAKING MODEL

Container terminals are very complex systems. Due to the dynamic nature of the environment a large number of timely decisions have to be continuously reviewed in accordance with the changing conditions of the systems.

Basic working parameters of the terminal (berth loading and unloading, yard loading and unloading, berth and yard occupancy, number of vehicles at the entrance in the terminal etc.) change continuously. Thus it is necessary to check and adjust them frequently. For such control, a vast number of programme tools are used, which are in most cases only intermediate tools. Those programmes are used for decision support and can be defined as an intermediate phase of planning, forecasting and optimization. The phase of optimization is the last phase of decision in terminal modelling, because the infrastructure and suprastructure of the terminal must first be defined, which is normally based on yearly container traffic forecast (by sea and by land). Thus the maritime container terminal must form an adequate decision model for short-term and long-term businesses and development decisions.

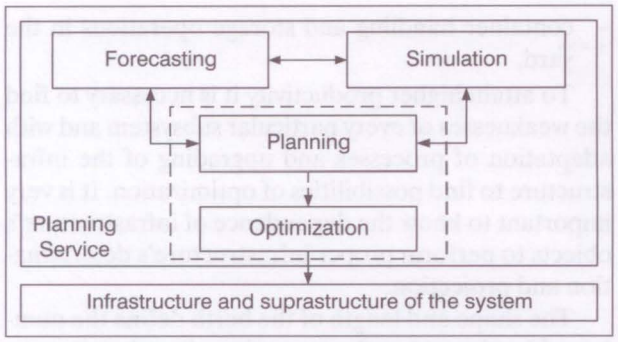
2.1 Organized planning service

The decision making model can be organized in the maritime container terminal through the planning service. The model is composed of three modules, which are in continuous interaction. These are modules of forecasting, simulations and planning with optimization segment (picture 1). We based on the modular system architecture[2] which was upgrade with the elements presented below.

The module of forecasting is composed of two sub-modules. The first module analyses the new technologic cognitions in the fields of transport, manipulation and storage (the development of container vessels, berth cranes, state-of-the-art systems for container storage etc.), which can be adopted on the existent maritime container terminal. The second module performs phases of forecasting the development of containerisation in the region and the traffic of containers through the terminal. The phase of forecasting is the key element, because it must foresee the needs and potentials to develop all the terminal's subsystems (subsystem of berth, subsystem of yard and handover subsystem) and at the same time enable an adequate planning and simulations application on the terminal.

The simulation module includes calculations of terminal's productivity parameters. With the simulation it is possible to set up the infrastructure and suprastructure of the terminal and to define the needed working processes. The module of simulation is also usable in case of an existent terminal, because with consideration of different number of manipulation equipment and staff education it is possible to achieve desired level of optimization.

The planning and optimization module is directly connected with modules of forecasting and simulations. The planning module must consider forecasts and cognitions acquired by simulations, and only in this way can planners optimize processes of the system and the structure per each subsystem. Different methods can be used for the optimization module, but empiric calculations are used very often (queuing theory, partial and total costs calculations etc). With calculations of the system activities, particular parameters of productivity and exploitation can be defined.



Picture 1 - The decision, simulation, planning and optimization model for container terminals

Source: Model worked out by authors

The proposed structure of the planning process enables the management of a maritime container terminal an adequate valuation of development possibilities of the entire system and possibilities to raise productivity. The goal of the decisions is to minimize the berthing time of vessels, the resources needed for handling the workload, the waiting time of customer trucks, and the congestion on the roads and at the storage blocks and docks inside the terminal; and to make the best use of the storage space. The main decision segments are:

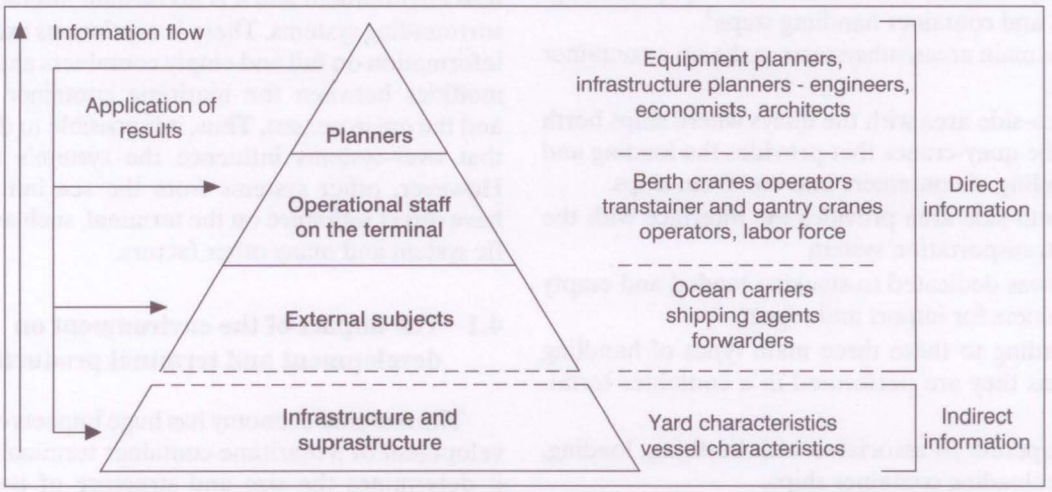
- Optimal activities of loading and discharging processes on all terminal's subsystems, in view of costs and needed time,
- Searching internal possibilities to upgrade system's activity,
- Defining capacity for optimal storage of the containers, in view of costs and needed time for operation,
- Making strategies for the future operation and development of the system.

Such a model must be the base for activities in the planning service of a maritime container terminal. This way balanced development of the terminal activities, constant development of the subsystems of the terminal, application of adequate processes per each subsystem and consecutively higher productivity can be achieved. Achievement of all mentioned factors leads to good financial operations of a maritime terminal, and with this to fulfilment of the main goal posed by the owners.

2.2 Collecting information to find an adequate solution

The planning service and management of a maritime container terminal must set up an adequate structure of collecting strategic information, in order to adopt adequate optimization ways. Proposals and possibilities of system optimization can be adopted on the suprastructure and infrastructure of the system. The model of planning service activities is shown in picture 2. Information flow on work facts has an upward movement. The pyramidal shape and proposed structure describe the hierarchy of decision-making and the level of responsibility for the adoption of cognitions obtained with simulations.

Systems and subjects from the surroundings also give important information. The national and international economies with their policy importantly influence the technical profile and physical flow of containers through the system. All the subjects who are in daily contact with a maritime container terminal (shipping agents, forwarders, cargo owners etc.) have a lot of applicable information, because they represent the interests of the cargo. Of course, ocean carriers are the most important subjects from the terminal's direct surrounding. They can have the maximal benefit only with optimal activities of the entire system. Thus their requirements and information are very important in strategic decision-making.



Picture 2 - Information flow and importance of decisions for terminal activity simulations

Source: Model worked out by authors

Operational staff plays a crucial role in collecting information, since cognitions of the labour force are based on actually registered work information during direct contacts with manipulation means and transport systems.

Proposed module of simulation put planners or planning service on a higher level. During their work they must take into consideration important cognitions and working factors of the entire system. With their new cognitions, based mainly on the planning activities, it is possible to form optimal operational and structural solutions for the entire system. Of course, the fact that those final decisions are taken by the owners of the maritime container terminal or with an adequate authorisation by the management of the maritime container terminal must also be considered. With such structure and organisation it is possible to qualitatively collect key data for good and oriented decision-making.

3. THE INFRASTRUCTURE AND SUPRASTRUCTURE OF THE TERMINAL

The infrastructure and suprastructure of the terminal represent the crucial basis for further upgrading of the system. The level of automation and technological equipment define working processes of the entire system. The highest level of connectivity and reconciliation must be developed between all subsystems and elements, in order to achieve efficacious development of the terminal. Moreover, high level of connectivity between subsystems has a direct impact on the entire production of the system.

The main function of a container terminal is to provide transfer facilities for containers between sea vessels and land transportation mode. It is a highly complex system that involves different equipment, operations, and container handling steps[3].

Three main areas/subsystems make up a container terminal:

- the sea-side area with the quays where ships berth and the quay-cranes that provides the loading and unloading of containers into and from ships.
- the land-side area provides the interface with the land transportation system
- the areas dedicated to stacking loaded and empty containers for import and export.

According to these three main types of handling operations they are performed in a container terminal:

- ship operations associated with berthing, loading, and unloading container ships,
- receiving/ delivery operations for outside trucks and trains,
- container handling and storage operations in the yard.

To attain higher productivity it is necessary to find the weaknesses of every particular subsystem and with adaptation of processes and upgrading of the infrastructure to find possibilities of optimization. It is very important to know the dependence of infrastructure's objects to perform proper infrastructure's determination and projection.

The shape and length of the berth define the number of berths and at the same time directly influence the length and number of rail tracks in the handover subsystem. The subsystem of yard is the key element for functionality or exploitation, where it is necessary to constantly investigate movements of handling equipment, in order to achieve higher level of space exploitation and undisturbed manipulation of containers. Faster work process performance can be achieved with the state-of-the-art mechanisation, which results in shorter dwell time of the container vessel and shorter queuing rows at sea and land side.

The information flow on condition and the infrastructure's efficiency is of extreme significance for strategic decisions of the management. All internal subjects (operators, labour etc.) have different and personal evaluations on the possibilities and needs to upgrade the infrastructure. The harmonisation of views and requests has very high importance on the achievement of an operational optimum, which exploit the infrastructure and suprastructure in the best possible way.

4. THE IMPACTS OF THE ENVIRONMENT AND EXTERNAL SUBJECTS

A maritime container terminal is a part of the business environment and it is in constant interaction with surrounding systems. There is continuous exchange of information on full and empty containers and on commodities between the maritime container terminal and the environment. Thus, it is possible to determine that over-systems influence the system's activities. However, other systems from the sea industry also have direct influence on the terminal, such as the traffic system and many other factors.

4.1 The impact of the environment on development and terminal productivity

The national economy has huge impacts on the development of a maritime container terminal, because it determines the size and structure of the flow of goods and the development and orientation of hinterland. International and national economies influence

the technologic profile and working capacity of the terminal.

Liner maritime traffic also influences the terminal's operations, because a higher number of liner vessels port touches make it easy for the port to find new partners and new goods flows. Moreover, the geographic position of the terminal is in direct connection with the number of competitive lines, and connections with the most important world and regional terminals.

Land transportation also has an important influence on container terminals, namely in two ways:

- With land connections, which determine the size and quality of the potential gravitational region, and
- With the number of continental transport means and the quality of services, which in combination with business policy of a maritime container terminal, also determine dimensions of gravitational region.

A lot of additional external factors have an influence on a maritime container terminal, like:

- Location and availability of the land for the terminal's expansion,
- Number and characteristics of container terminals in the nearby locations,
- Local, national and regional traffic policy,
- Ownership and the management structure in the port and the port's policy as a system,
- Scientific and technical progress in nearby environment and on a global level.

Location and land availability enable further expansion of the terminal, which is always connected to high financial investments. Terminals with limited expansion possibilities have limited capacity and their development at the existing location is practically impossible. At the same time unused land determines the terminal's shape and the location of every single subsystem.

Traffic and port policy have a key function in further development of container traffic in the region. Higher possibilities of unproductive system activities are usually in places where the port policy is not clearly defined. Such circumstances can lead to intensive development or to retro-gradation of port activities. In addition, the ownership structure has also a deep influence on the development policy, which is reflected through investments, business decisions and long-term activities orientation.

4.2 External subjects

Besides over-systems and subsystems, direct users of terminal services also have impacts on main activities of maritime container terminals. Direct users of port services are different external subjects and their business depends of terminal's efficiency. Surely, the most important external subjects are ocean carriers.

Opposite interests exist between the ocean carrier and container terminal. Ocean carriers request shorter dwelling time for their vessels, and on the other hand, the terminal operator would like to do higher throughput with lesser number of berths and manipulation machinery. Ocean carriers value the competitiveness of maritime container terminals through different measurements (berth productivity, dwell time on berths and shorter waiting time for a free berth).

Besides ocean carriers, other business subjects are important too. These are forwarders, shipping agents, global logistics companies, trucking companies etc. They all have the same expectations from the container terminal. Their information is of crucial importance to the activities of planning service, because they take an active part in the development of a maritime container terminal. Local subjects have essentially less influence on the operator's business decisions, but their information is also very important to find optimal operational and development strategies.

5. IMPORTANCE OF OPERATIONAL STAFF'S INFORMATION

All the employees on a maritime container terminal have important information about every single subsystem of the terminal and about the terminal as a whole. Their daily work gives them detailed information about present working weakness, possibility to define bottlenecks and possibilities for system's optimization. Of course, their accomplishment is limited mainly to knowledge about work processes and technological working procedures, but they are an important source of information.

Planners and terminal operators must develop an adequate stimulation system, in order to develop an appropriate network for data collection. The operational staff must recognize itself as a key element in the future development of the system, in order to actively cooperate in the system's modelling. Successfulness of staff's inclusion in the development processes is directly connected with its present status in the system. It is reflected through social situation, safety conditions, and financial policy and through the management's understanding in cases of troubles and entanglements.

Proper stimulation of the operational staff (to give important information and proposals) can be done in different ways, like: periodical financial remunerations for high response level or financial payment for good proposals or improvements. In such ways a critical number of employees can be stimulated to cooper-

ate, but in the next step an adequate way of communication must also be settled (regular or periodical meetings, periodical workshops, IT programs and solutions etc.).

6. PLANNING SERVICE AND THE MANAGEMENT OF THE TERMINAL

Planners must know the difficulties and bottlenecks on the terminal, because only in such a way can they work out adequate solutions. The order of decisions precedence must be congruent with the needs to increase productivity and with higher financial results. Planners use information flows to set up a decision model; how to manage container flows, how to increase the productivity of the present system and how to achieve desired level of optimization. To achieve the desired level of optimization it is necessary to coordinate activities of modernization and optimization of each subsystem's capacity. In case some processes are optimized separately, they contribute to the total positive effects of investments in the terminal's modernization. In this aspect the organization's structure of collection and processing strategic information is a key factor.

Planning elements must first locate bottlenecks of terminal capacities and then after also their impacts on other subsystems and processes. It is very important to analyze impacts of higher productivity of one subsystem on other subsystems, in order to avoid the exact opposite effects on all other subsystems. With a higher level of automation it is possible to achieve higher productivity, because new mechanization has higher efficiency and enables a higher number of manipulations per time unit. In spite of everything, the use of only the efficient suprastructure cannot guarantee the optimization of the system (e. g. acquisition of efficient container cranes increase container handling per hour, thus the vessel is unloaded faster, but the berth efficiency must also be considered, because it can be badly exploited and the investment is economically unsuitable).

In practice it is very difficult to determine the dimension and the optimal capacity of a maritime container terminal, because of irregular vessels' arrivals and duration of unloading manipulations. The system should have at disposal some reserve capacities, in order to accept and unload or load all containers in arrival or departure. Such system reserve capacities contribute to lowest terminal efficiency and undoubtedly increase fixed costs.

The management of a maritime container terminal does not want long queuing rows at sea and land side, because these facts can influence the carrier's decisions to leave the terminal and to move its services to the neighbouring ports or container terminals. At the same time, lower efficiency of the infrastructure and suprastructure of a maritime container terminal increase working costs, which the carriers feel through higher costs of terminal services.

7. CONCLUSION

Dynamic development of global economy and containerisation, as contemporarily technology of goods transfer; force maritime container terminal systems to continuously upgrade their infrastructure and suprastructure. Consecutively the need to set up an adequate decision-making model for short-term and long-term business and strategic decisions appears.

The proposed and described model of planning activities enables the management of the terminal, a suitable valuation development possibilities and productivity increase. All three described segments are very important and a high level of reconciliation between them must be present, because there is a constant interaction of material and information flows among them.

For proper model function it is necessary to set up adequate and efficient information collecting system and a system of key information valuation. Proposed model of collecting information organization includes all the components, which are of crucial importance for an efficient strategy making about the future business and development. Planning service must offer the management the highest level of expertise, practically in all segments of planning. With such structure it is possible to achieve balanced development of the entire system and long-term planning activities, which satisfy expectations and needs of all external business subjects.

Dr. **ELEN TWRDY**
E-mail: elen.twrdy@fpp.edu
Univerza v Ljubljani, Fakulteta za pomorstvo in promet
Pot pomorščakov 4, 6320 Portorož, Republika Slovenija
Mag. **BOJAN BEŠKOVNIK**
E-mail: bojan.beskovnik@intereuropa.si
Intereuropa, Globalni logistični servis, d. d.,
Vojkovo nabrežje 32, 6000 Koper, Republika Slovenija

POVZETEK

PLANIRANJE IN SPREJEMANJE ODLOČITEV ZA DVIG PRODUKTIVNOSTI NA PRISTANIŠKEM KONTEJNERSKEM TERMINALU

Članek opisuje usmeritve optimizacije delovanja na pristaniškem kontejnerskem terminalu. Z uporabo ustreznega modela napovedovanja, planiranja in simulacije se lahko poveča produktivnost ter optimizira zmogljivosti terminala. V članku je poudarek predvsem na postavitev modela sprejemanja us-

treznih odločitev za dvig produktivnosti na vseh podsistemih pristaniškega kontejnerskega terminala.

Upravljanje pristaniškega kontejnerskega terminala je kompleksen proces, ki vsebuje veliko število različnih odločitev. Menedžment mora razviti elemente in strategije za preverjanje produktivnosti in njen dvig, kar je možno doseči z optimizacijo delovanja celotnega sistema. Lažjo uporabo različnih strategij, ki izboljšajo produktivnost, je možno doseči s poznavanjem novih tehnologij, delovnih procesov, metodami napovedovanja in simulacije. To še posebno velja za terminale, kjer je fizična širitev terminala praktično nemogoča in je možen nadaljnji razvoj sistema samo z iskanjem notranjih resursov. Menedžment pristaniškega kontejnerskega terminala razviti ustrezen model podpore odločitvam, da se omogočil podporo strateškim odločitvam. Te odločitve se nanašajo predvsem na vrednotenje najboljših razvojnih in optimizacijskih odločitev, ter na aplikacijo predlaganih rešitev v infrastrukturo in suprastrukturo terminala.

KLJUČNE BESEDE

pristaniški kontejnerski terminali, produktivnost, model odločanja, planiraje

REFERENCES

1. **Günther H-O, Kim K-H** (2006) *Container terminals and terminal operations*. OR Spectrum 28:437-445
2. **Gambardella L.M., Rizzoli A.E., Zaffalon M**: *Simulation and Planning of an Intermodal Container Terminal*, IDSIA - Istituto Dalle Molle di Studi sull'Intelligenza Artificiale
3. **Steenken, D., Voß, S.**, and **Stahlbock, R.** (2004). *Container Terminal Operation and Operations Research - A Classification and Literature Review*. OR Spectrum, 26(1):3-49.

LITERATURE

[1] **Choi, Y. S.**: *Analysis of Combined Productivity of Equipments in Container Terminal*, Korea Maritime Institute, Maritime Review, Vol. 3, 2003, p. 57-80

[2] **D. Steenken, S. Vob, R. Stahelbock**, *"Container terminal operation and operations research"*, OR Spectrum, Springer – Verlag, 2004

[3] **P. Franke, K. Alicke, D. Arnold**, *"Modeling and optimization of the intermodal terminal"*, IHL, Universitat Karlsruhe, Karlsruhe, 2001

[4] **I. A. Hansen**, *"Automated shunting of rail container wagons in ports and terminal areas"*, Transportation Planning and Technology, 27, 5, 2004, pp. 385-401

[5] **H. Bielli, A. Boulmakoul, M. Rida**, *"Objected oriented model for container terminal distributed simulation"* European Journal of Operational Research, 2005, pp. 1-21

[6] **E. Peterlini**, *"State of the Art of conventional and innovative techniques in intermodal transport"* EUTP, Brussels, June, 2001

[7] **Imai, A, Nishimura, E** and **Papadimitriou, S.** 2001: *The dynamic berth allocation problem for a container port. Transportation Research* Part B 35: 401–417

[8] **Günther H-O, Kim K-H:** *Container terminals and terminal operations*. OR Spectrum, 2006:437–445

[9] **Steenken, D., Voß, S.**, and **Stahlbock, R.** (2004). *Container Terminal Operation and Operations Research - A Classification and Literature Review*. OR Spectrum, 26(1): 3–49

[10] **Gambardella L. M., Rizzoli A. E., Zaffalon M:** *Simulation and Planning of an Intermodal Container Terminal*, IDSIA - Istituto Dalle Molle di Studi sull'Intelligenza Artificiale