Port operation – increase of automated systems, decline of workforce jobs?

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***Abstract*—** As ports are worldwide centers of intermodal changing in transportation of goods, since last years of the nineteenth century are increasingly equipped with lifting and cargo transportation equipment. By this way, both the massive mechanization of the activities and the evolution of automation technologies opened the window of opportunity to change processes and use of systems with automatic controls, as long as the number of dockworkers decreases. In several industrial plants, the effects of these changes are quite visible, as long as result in increased production and lower risk exposure. However, from the point-of-view of jobs opportunities, the inverse is not strictly proportional, in comparison with significant people reduction. The use of robots in industrial manufacturing led to the emergence of so-called *lights out* processes or *dark factory*. Considering the new trend in progressively mechanized/automated cargo terminals, the displacement of port workers for other activities is very real and intense. Regarding some peculiarities and characteristics of multipurpose terminals handling in ports, will this trend dominate for the foreseeing future? This article discusses this question in three parts: automation, port automation and the effects of mechanization, automation and possible consequences for jobs and work in ports.

***Keywords*—** Automation, Port Automation, jobs and workforce.

I. Introduction

THE cargo movement in ports undergone a worldwide transformation. The infrastructure of port waterfront, berths, facilities have evolved considerably, making it capable of supporting efforts from load requests of thousands tons arising from equipment appliances mounted.

The mechanization and the introduction of container led to the reformulation of shipping transport and the whole operation in ports. The automation of port systems brings continuous advances. Cargo handling reach increase amount meanwhile, for workers, it is observed a severe reduction of jobs. This paper addresses this issue in three stages: automation, port automation port and discussion of the effects on dock work.

According to historical records dating back to 270 BC, Vitruvius studied possibilities of a clock powered by water, apparatus referred to as rudiments of automation.

In productive activities, it is considered replace work and human efforts by devices and equipment that have better overall result, concept called mechanization.

In an applied way, we have the progressive use of tools and systems based on physical principles related to: work, momentum, power, hydraulic and pneumatic pressure, wind, gravitational, thermal, electric, solar power, etc…

The development of mechanisms and equipment and its incorporation into the organized production dates back to the period of so-called Industrial Revolution, with the classic example of the looms with drives the steam produced in boilers and mechanical sets of motion transmission as cylinders, piston, piston rods, shafts, pulleys, rotors, cams, distribution gears, etc.

According to Mamede Jr [1], "from the industrial revolution, muscle strength gave way to machines," by mechanized production.

The systematization of productive activities allowed the occurrence of the second industrial revolution, the implementation of the assembly line, in the early years of 20th century, with the large-scale production of the products.

Therefore is widely accepted that the process of mechanization is a preliminary step in gradual trend on enroll in to automation systems.

Automation sets the basis for the third industrial revolution, the revolution resulting from the digital age. Thus, in a reverse cycle, a large scale production provides a possibility for manufacturing using high technology even for few quantities with compatible costs, starting with sophisticated sets as jet engines.

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II. INDUSTRIAL AUTOMATION

Some authors indicate Automation is a neologism from automation, and refers to the use of technology to facilitate the work of human or extend their physical and mental capacity.

Control and automatic control refers to the use device (controller) that without the help of human action make a system behave the way you want.

Among the areas of knowledge involved in automation, we have the inter sciences: mechanical, electrical, electronics, telecommunications and information systems.

This consideration is quite important, as they relate Zugge, Pereira, Dias [2], "the problem is frequent considerable that a lot of information does not create any knowledge". In addition, recommend for the improvement of systems the integration between IT (Information Technology) and AT (Automation Technology), "Nowadays some companies are investing a lot of money and effort to integrate IT and AT. However, some companies have not been achieving the success they expected "which indicates the complexity of this improvement".

III. HIERARCHY LEVELS OF INDUSTRIAL AUTOMATION

Industrial automation can take various roles in industries, since the automation of an operation to a large set of sequential activities, with the participation of so-called industrial robots.

Facing to the diversity of production processes, there are different types of classification called Automation Level. The table below shows the traditional model Purdue Reference Model, levels basis for the standard ISA 95.

Table 1 - Purdue Reference Model PRM

Levels	Description
5	Business Systems, strategic planning and corporative management
4	Plant level, production and programming, ERP, MRP and MES
3	Operation Unit Level
2	Machine/Process Automation Level
1	Controller Level
0	Sensor/Actuator level

Lydon, B [3] points to a technology evolution that could simplify that level hierarchy, as "more controllers are supporting multiple Ethernet ports to interact directly with industrial and business network that exists throughout industrial plants".

In other way, Rother M Harris R. C , [4] describe a hierarchy that consider systems subdivision with different levels of automation in its subsystems or processes, also said semiautomatic, where there is partial involvement of manual action.

Table 2 - Adapted from Rother M. Harris R,.LEAN directions

LEVELS		Machine Load	Machine Load	Machine Discharge	Transfer Parts
	1	Manual	Manual	Manual	Manual
	2	Manual	Auto	Auto	Manual
	3	Manual	Auto	Auto	Manual
	Main Division				
	4	Auto	Auto	Auto	Manual
	5	Auto	Auto	Auto	Auto

And also explains "level three offers the most efficient and flexible combination of the movements of the operator and materials."

IV. PROCESS AUTOMATION – INDUSTRIAL PLANTS

The market competition makes the automation of processes in the industrial area a very important condition, with the increasing deployment in the assembly lines of automated procedures, using robots and mechatronic devices.

By the automation of production, the industrial sector has advanced considerably with the introduction of robots in assembly lines.

In a compact physical space of the production line, robots replace humans with speed and efficiency, especially in repetitive and dangerous tasks with greater potential risk of accidents.

The nature for the related process has distinct impacts behold production conditions usually defined in industrial plants.

For production planning, the limitation of time and space, with constant repetition of movements, paths and routes are likely to be supplied and standardization within the degrees of freedom of movement of robots.

An important reference is called standardized time, or simply *takt time*, that Rother M, Harris R. [5] at LEAN methodology describe as "the rate at which the finished product needs to be completed in order to meet customer demand," so, described mathematically, *takt time* is:

Available time for production / required units of production

Nowadays, the *digital hortator* beats by software and hardware the rhythm of industrial operations.

V. PROCESS AUTOMATION – INDUSTRIAL PLANTS, DARK FACTORIES

Many industrial manufacturing units are named manufacturer, referring to the Latin word for to handmade, or handcraft, i.e. to make something by manual skills. Industrial sector uses strongly automation on the assembly lines considering the usage of robotics, mechatronic devices, pneumatic systems and other types of automated systems.

Conditions defined for industrial plants as production and

process characteristics favored this transformation.

The growth of this production system induces, at its limit, to a highly robotized production environment, where the man participation is minimal, practically restricted to the supervision and control of the continuity of processes.

This automation, robotics where the drive eliminates the lighting, result "manufacturing lights out" processes, and industrials plants also known as "dark factory". The need for lighting is the human controller of the process, at least for repairing, adjusting jam although mainly focusing on system supervision.

This situation was not yet effective for several reasons, including the complexity of the robots and their high costs of implementation and operation, requiring expensive specialists.

Still, some areas of production such as plastic injection, laser cutting and printing have made significant progress in automation.

The increased use of robots in factories will be possible with the advancement of technology, allowing less expensive costs of acquisition and set up robots, in order to simply the operations in great scale, and even more productive.

Currently, industrial production processes still consider as high valuable the participation of man, in new tasks in which the abilities and skills are useful.

VI. PORT AUTOMATION - INTRODUCTION

The application of automation in port processes in the movement of goods led to structural changes.

As well known, the transportation of goods from the coast to the vessels along centuries was performed by smaller boats - with the climatic difficulties of sea currents and waves.

This situation stimulated, where possible, the construction of precarious wooden structures to where the draft allowed positioning the vessel, for a dry access to the ships.

The building of safe pier docks with solid structures in areas protected from the weather (and also from pirates), brought the ship moored closer to waterfront, accessible platform for animals and land transport vehicles, and implementation of deposits near the berth, adjusting production to ship traffic.

The stable bases permitted to developed specific equipment for lifting and transport of loads that, according P. Alfredini, E. Arasaki .[6] should consider the continuity of operations without times waist in intermediaries of equipment operations, by the use of temporary storage areas with multifunctional devices.

VII. AUTOMATED VESSELS

The continuous advancement in technology brings every day new automated ways in the movement of goods. Therefore, companies started to design cargo carriers without onboard crew, considering remote operation.

This condition has resistance in several countries, facing to the current lack of security guarantees, mainly environmental.

On the other hand, presents itself as a perspective for the near future, operating in the marine environment like the drones aerial vehicles VANTs (unmanned) or VARP (remotely piloted).

VIII. AUTOMATED TERMINAL

In containers terminals, the fundamental rules of logistics guide the design of load plans by the ship planners, considering the sequence of ports at which the ship will operate, according that “the first a load is boarded the latter will be removed”.

The relative position of the containers in the ship hold, (inside), or on the deck (outer), is referenced spatial orientation relative to the ship (bow, stern, portside, starboard), according to the position set on the loading plane array. Bay (longitudinal) and row (transverse) consider a horizontal plane, and the vertical tier position.

Fig. 1 presents the bay, row and tier positioning.

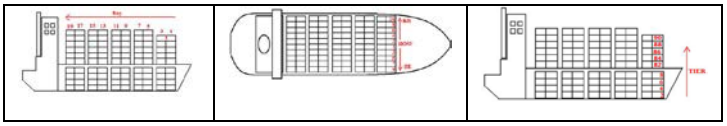

Fig. 1 - Bay, row and tier positioning. Containers loading matrix. Image adapted from Oceanica UFRJ.

Regarding its capacity containers, vessels are indicated as shown at table 3.

Table 3 - Adapted from oceanica UFRJ

Number of TEUs	Vessels Types
< 1000	Small feeder
1001 - 2800	Feeder
2801 - 5100	Panamax
5101 - 10000	Post Panamax
10001- 14500	New Panamax
> 14500	ULVC Ultra Large Container Vessel

Nowadays one of largest ship in operation at the time, CSCL Globe, with a capacity of 19,000 TEU, moored in Rotterdam in January 2015. It also announces the construction of a new ship for more than 20 thousand TEU.

For the East-West route, the main in terms of cargo volume, these super ships are supposed to operate mainly in the future channel of Nicaragua with planned capacity for vessels up to 25,000 TEUs or 400 thousand tons. The Panama Canal, even with the current expansion, had its capacity increased up to 15,000 TEUs or 150,000 ton (New Panamax).

IX. AUTOMATED OPERATION IN CONTAINER TERMINAL

When ship is moored at the pier and its position is validated, this condition also validates up the spatial position of each container indicated in the matrix structure of the cargo plan, allowing the start of operations.

From the ship plan, based load plan, along with the movement of the lifting equipment, an automated operation the “carousel" of trucks driven by programming can start the

journey with stroke and established operation, integrated with other equipment such as reach stackers, RTG (rubber tired gantry crane) RMG (rail mounted gantry crane) transporters and quarry gantry cranes.

Port operations Multi cargo ports:

Producer to → Regulator yard→ Port Terminal → ship
Generic boarding algorithm

Port operations could be realized in many levels of mechanization and automation. Equipment considered for each material and mode of transport, road, railway, waterway and pipeline. In smaller scale, the use of lifts and airport connections systems.

X. OPERATION WITH CONTAINERS – GENERIC BOARDING ALGORITHM

Producer to	Regular Yard	Port Terminal	Ship
Truck Arrival Notification	Standby Scheduling Authorization Continues Trip	Access Identification Positioning Control Equipment Discharge (forklift/reach stacker /rtg) Loading Truck Transport Positioning Quarry Crane/LTM	Receipt Positioning Bay/Row/Tier Lashing Liberation Ship Deliver

This is a type of mechanized operation with good prospects for automation in ports and terminals.

Since receiving the container in the terminal entrance, access control, positioning in the courtyard, integration into the cargo plan, the mobilization to the sideline, loading on board in ship hold or deck.

On arrival at the port of destination, repeat the sequence in reverse order, according to the containers schedule.

XI. OPERATION OF DRY BULK – GENERIC BOARDING ALGORITHM

Producer to	Regular Yard	Port Terminal	Ship
Truck Arrival Notification	Standby Scheduling Authorization Continues Trip	Access Identification Positioning Control Equipment Discharge (Hopper/Elevator/ conveyor/Tripper) Load (Carrying Shovel) Hopper/Elevator/ conveyor Ship loader	Cargo Hold Receipt Liberation Ship Deliver

The solids unpackaged, bulk are generally derived from products:

- Vegetable - sugar, cereals (maize, soybeans, wheat, and others) pellets. These products are dependent of protection against moisture and must be packaged in appropriate warehouses.
- Minerals: sulfur, phosphate rock, bauxite, salt, coal and raw materials for fertilizers among others. According to the particle size and other physical characteristics, the products could stay in a open yard.

The packaging of bulk solids requires protection systems and environmental control, and workers. According to the particle size and other physical characteristics, plant products are flammable and require protection systems and firefighting.

Ships for bulk solids transport must be equipped with the appropriate holds to receive loads, busy with cargo equipment or continuous discharge or batch.

Table 4 describes capacity for bulk carriers.

Table 4 - Capacity for bulk carriers. Adapted from http://www.worldtraderef.com/WTR_site/vessel_classification.asp

Capacity dwt	Vessels Types
10.000 to 30.000	Handy Sized
30.000 to 50.000	Handy max
50.000 to 80.000	Panamax
80.000 to 200.000	Capesize
>200.000	Very large ore carriers
400 mil ton	Valemax

The bulk solids for export is received at the terminal from trucks, waterways barges or rail cars with discharge hoppers.

For the unloading of trucks is often the use of the truck lift system, and gravity unloading the posterior position of the cart.

Railway wagons have bottom opening and systems to discharge directly into the hoppers.

The hoppers are willing transported on belt conveyor for yard or warehouse conforming trapezoidal piles from mobile discharger from a structure tripper.

Another form of storage are warehouses of grains, generally circular and high dimensions that generates concentrated loads, which require special soil foundations.

At the boarding operation, bulk is loaded with belt conveyor that carry the products directing to the holds of ships equipment called ship loaders. When are used bags the ship loaders are provided with a dispensing reel.

In reverse operation, the ship unloader, the discharger removes the vessel's hold material grabs or suction, according to the product characteristics. Hence, after discharge into a hopper, it is transported to the warehouse or directly to trucks and wagons.

XII. Liquid Bulk – Generic Boarding Algorithm

Producer to	Regular Yard	Port terminal	Ship
Ducts Notification Pumping	Receipt Stock Scheduling Connection Ducts Notification Pumping	Receipt Stock Scheduling Connection Ducts Notification Pumping	Cargo Hold Receipt Liberation Ship Deliver

Traditionally, liquid bulk is one of the most automated forms of goods handled in ports. The predominant cargo are fuels of mineral or vegetable origin, vegetable juices, liquefied gases, chemicals.

They always are careful operations that require strict compliance with safety standards to avoid disastrous occurrences.

The placing product in tanks requires holding basins for any leaks, level control devices, pressure, and temperature. In the discharge and suction operations, the safety valves have special care, as well as grounding systems and prevention systems, monitoring and automated firefighting.

It is known that even small electrostatic charges may cause sparks and harmful consequences in environments with potentially flammable materials and explosives.

The liquid bulk from tanks is pumped into the vessels hold; all with the preventive measures the terminal itself or port PAM - Mutual Aid Plan - when necessary Publication Principles

XIII. General Cargo - Generic Boarding Algorithm

Producer to	Regular Yard	Port Terminal	Ship
Truck Arrival Notification	Standby Scheduling Authoriza-tion Continues Trip	Access Identification Control Equipment Discharge (Forklift/Reach Stacker/Rtg) Loading Truck Transport Positioning Quarry crane	Receipt Positioning Bay/Row/Tier Lashing Liberation Ship Deliver

Products not classified as containers or bulk are referred as general cargo.

Several products are moved packed in bags of various sizes. More recently, in large bags. Also drums, coils, profiles, ingots, bales, etc .

Transport could be combined on wooden pallets or tied pieces or slings

Still under the general cargo designation are included big parts of project cargo or special sets or large unit equipment, volumes or masses, such as turbines, electric transformers, rotors, locomotives, cranes, propellers of wind generators, quarry cranes, RTG cranes, wagons, locomotives, rails, ships, with brackets and specific lugs for connection of lifting and conveyance. If necessary, are used specific vessels for special transport.

For this study highlights the cargo of wind propellers, the difficulties lifting, positioning and locking of packaging. There is no automation in this operation.

XIV. Prospects For Automation – In Addition to Efficiency, Safety Automation IN TO the ports

About security in domestic and foreign concept of a port or terminal, highlights the IHMA- International Harbour Masters Association [8] is:

"Most, if not all, navigable rivers, channels, ports, harbors and berths are subject to danger from, for example, tides, currents, swells, banks, bars or revetments, traffic density and changes in depths.

And continues: "Such dangers are frequently reduced by lights, buoys, signals, warnings and other aids to navigation and can normally be met and overcome by proper navigation and the handling of a vessel in accordance with good seamanship. And concludes: "The reputation of a Port is largely dependent on its safety record and efficiency. Any damage to a port's safety record may affect on its reputation and by extension, its trade" Many ports have their own VTS – Vessel Traffic System, for controlling arrive, port activities and depart of ships.

About safety, the commotion caused by accidents and personal injuries must be considered as the port environment

influences directly to the worker safety and integrity, his family, the work team, and even relationship social circle, feels the impact of any accident victimized by the worker.

Accidents tend to cause breakdown of the teams motivation contaminating the work environment, underscoring due to their frequency and severity.

However, how society acknowledges and judges accidents?

Thus, the moral and social losses are exacerbated by the ratio of fatalities and perception, as presented in IMO-FSA [9], which demonstrates the public aversion to accidents when he says:

"Society in general has a strong aversion to accidents with multiple victims. There is a clear perception that a single accident victims in 1000 is worse than 1000 accidents in which dies (kills) a single person."

If, on the one hand there is a spectacle more severe injuries, on the other notes to popularization of smaller, affecting the balance of his analysis and correction. Mechanized equipment and automated systems must have operation conditions that preserve people that operate them.

XV. Ports, Automation and Production Workforce

A. Socioeconomic aspects and conflicts at work.

The implementation mechanisms with increasing production capacity have correspondence with the reduction of jobs in these activities. This situation led to armed conflict as referred to historically playfulness, social movement in the second decade of the nineteenth century.

Led by Nelson Ludd, aggregated workers who mobilized against replacing workers with machines, invaded industries and breaking equipment. Afterwards, unions appeared to collectively fighting over workers' rights.

B. Automation and work

On systems with self of automation, should be avoided human presence restricted to authorized circulation areas, so should not remain people to avoid accidents, even with sound from handling equipment when moving.

It is what is observed at the terminals where automation is implemented progressively reducing up the human presence in the courtyards. These act in the control and supervision of the process steps. Centralized automation system provides a possibility for the operator to monitor and control field area by checking high-resolution cameras. An actual example is the Euromax terminal in Rotterdam.

These terminals due to their level of automation seem like ghost terminals, where is not allowed people stay in the cargo area.

Its main feature is the reduction and even elimination of direct human participation in the activity, with the man in the monitoring and supervision. It follows from the cost savings resulting from energy saving, and materials, improving the accuracy and quality of operations.

The automation of operations and processes frees man's work in repetitive activities and unfavorable conditions in which there is discomfort and potential risk of accidents and illnesses. The reduction of costs related to the work reflects the lower application hours and related charges.

So with less human involvement, expected better quality and productivity, with fewer accidents due to fatigue and tiredness. Additionally fewer complaints and wage demands.

However, even in the most automated processes in dark factories, have not yet reached projected results, the basic finding of the operational difficulties of adjustment processes, which confirms the finding that the most important in the production process are people prepared to realize it and driving it.

Hence the contribution that experience and knowledge are fundamental to success in the processes. They should be the subject of care in their preservation and enhancement for transmission to reviewers.

C. Port jobs and workforce

Process automation - terminals and non-specialized port facilities

The goods handling environment in the ports of various loads differs significantly, almost in opposition of the processes in industrial plants, since in them notes the diversity of goods, work areas, actions to develop and mainly of agents who perform, workers.

For the workers, every period change the places where carry out the activities, ships to be operated, the corresponding goods and procedures, co-workers, the hot / cold climatic conditions, the periods of day / night, natural light or artificial, or even the night pitch of the paths between rows of containers.

In cases where partners and staff members are permanent, it is natural to develop collective skills, interaction for knowledge, in synergy characteristic of team game that allows influence for improvement.

In these teams, alternating hierarchy at every turn, knowledge also requires frequent training to perform multiple tasks, lead and organize.

The intensive use of human labor in working conditions under hard working conditions, characterized long period until start the utilization of large equipment mechanization that caused the deployment of people.

At the beginning of the use of clamshells as implements of cranes for bulk handling, tells us T.C. Zotto .[7] about the gunshots from angry workers in the first grabs, similar to actions such as the attacks and destruction of equipment of the industrialization period.

From the port worker point of view, even arduous working conditions are important to support subsistence of themselves and their families. Hence the historical reaction to processes that reduce jobs.

However, for a long time, the man remained the major force element in the movement of goods on board ships and ashore.

The use of lifting equipment and cargo handling evolved the capacity of quickly load ships to increase the number of trips and dispose of goods to destination markets. This evokes the observation of K. Marx [10] in the mid-nineteenth century:

"You can ask if all the mechanical inventions made so far lightened the daily work of any human being", since the true intention of the capital was to reduce the price of the goods.

In contemporary terms, T. Picketty [11] manifests one of the expressions of this bias automation in his work "The capital in the XXI century", which argues that (r) rate of return on capital will fall slower than (g) rhythm economic growth.

Hence, if it is sufficiently easy to replace workers with machines, if the elasticity of substitution of capital for labor is greater than one, widen the gap between *r* and *g*. thus concludes an immediate consequence of redistribution of income, workers in return for capital.

D. Changes in dock work - Containers, production and jobs

Port work at early years of the twentieth century was still essentially manual. Huge queues of workers carrying bags in the back were the typical views of labor between warehouses and ships.

At the end of the twentieth century and the beginning of the current, was the multiplication of cargo movement, fostered by the dynamics of the economic situation and facilitated by the automation of processes, with the "revolution" world due to the intensive use of containers, with loads of all kinds put in charge safes.

This conceptual change leads to what F. Bruno et al. [12] refer to "the simple thing the container did was sharply lower the cost of shipping goods from one place to another. However, the container revolution also changed the mechanics of shipping: the logistics, the speed and capital's structure ".

Add that the use of containers provided for the conditions, and the mechanization of the operations, the automation of the terminals.

“that containerization is a monument to most powerful law in economics, that of unanticipated consequences””.

And about jobs reduction, continues Fabiano [12]: “labor leaders feared the container, but even they were not prepared for the speed with which destroyed ”water-front-job”, against the prediction of 30% reduction, in reality 75% has vanished by 1976”.

Port activities implementation are traditionally held by temporary contracted workers, strongly aggregated into their own unions, with great tradition of defending their categories.

How then place the reduction of temporary dockworkers? The Brazilian law of port modernization has established the creation of OGMO - Organization for Labor Management, by replacing the workers of the Port Authority. In addition, policies for training and redeployment of workers.

Modern equipment has operational characteristics that allow the operator to go through a preliminary training simulator to know the movements and possibilities. Then, when it is demonstrated the ability (skills) enough, supervised training takes place in own equipment under limited conditions to acquire the resourcefulness needed to take the solo operation.

Equipment manufacturers developed simulators systems with workplaces similar to the operating equipment, sensors, controllers and speed adjustment devices, range, and other control measures of the operation.

Thus, the increasing mechanization and automation in port and multipurpose cargo terminals are incipient, and progressively increased by the incorporation of technologies directed to the speed and intensity of movement, creating complex situations that require constant attention.

XVI. CONCLUSION

About automation influence in production activities, McMillan [13] observes that: “People make errors. Automation has been very successful at reducing these errors although it may just be relocating human errors to another level.”

In addition, continues, “A person is still needed for performing cognitive-based tasks, as another system check and provide needed flexibility for unexpected events”.

When people experimented is been pushed away from the workforce, more specialists systems are required, to support decisions. The results may be not the same.

Thus, for multimodal terminals and ports, the present situation is certainly still far away from the so-called *ghost terminal*, where intense automation and consequent reduction - *invisibility* - the absence of human work would be the compared to *dark factories* of industrial activities.

If, for advanced cultures is understood that automation displaces people from dangerous function, painful and exhaustive, more and more the training people to work in automated systems is required for repositioning of workers.

Ports applications of automated systems must preserve for a long time the workers contribution, based in skills and experience, ability for prevent and problems solutions.

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