The Logistic Game®

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Abstract

The aim of this paper is to describe an innovative Logistic Game® developed by the authors. It creates a competition between different teams in terms of strategic decisions in logistic and production problems in a real production system. The game is innovative in three ways. The first is the type of game. It is a game representing a production and logistic system, with the dynamic problems of a real system where, with finite resources, decisions have a relevant impact on performance. The second is the application of a simulation package to create the real scenario in which the competition develops, with the possibility to consider all factors (WIP, down times, line balancing, skills of person, etc). The third is its possible applications, since the game can be used not only as an educative facility, but also as a tool to assess the management skills of a future/present manager to face real and dynamic logistic problems.

Keywords: Logistic Game, Game, Operation Management Education, Simulation.

1. Introduction

Many definitions of *game* have been given in literature. Bowen defines *game* as ‘‘people, individually or in groups, that are in a competitive situation (Bowen, 1978). They have resources they dispose of according to rules, dealing with losses/gains…moves may be simultaneous or sequential. They develop strategies for winning and make and implement decisions”. This definition is suitable for all kinds of games.

Why is it important to have operation management (O.M.) games? This interest in ‘playing’ can be explained in a number of ways. First of all through games and simulations we avoid the risk of confining students to an entirely theoretical setting. According to Ammar and Wright, ‘‘the interesting and challenging issues are difficult to convey effectively in a purely theoretical setting because students need some way to directly experience the issues involved in operating a production system’’ (Ammar and Wright, 1999).

This is the specific reason for the development of new O.M. games and thus of the Logistic Game®. It is called Logistic Game® because it is a game about logistics, which is “the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption with the purpose of conforming to customer requirements." (Reference: Council of Logistics Management, http://www.clm1.org/mission.html, 12 Feb 98).

Once the target market demand is established, parameters are set to entirely satisfy it with an integrated approach to the whole production system of the game, which consists of 3 main sub-systems: a manufacturing system, a material handling device system and an assembly system, optimizing the physical and information flows and minimizing the installation of the resources.

There is the necessity in a management engineering course to have the possibility to test, in a real industrial environment, the ability of the students to face real strategic decisions and their effects. Finite capacity, performance of the whole integrated system and challenges with other teams, which are to be seen as competing companies in a real market, are all elements that make the game good training experience in operating in a logistic system.

The O.M. game introduces some highly innovative ideas concerning the environment and how to achieve it. It creates a modern logistic and production system in which teams elaborate strategic decisions with input data (rules, target, facilities data sheet, previous results) in order to obtain the definite output. This is achieved using a modern simulation package that re-creates the logistic and manufacturing system in which competition evolves. The possibility to see the production system running, to obtain a complete performance report and a support data base application developed by the authors, give the game a "real-application" character.

But why is an O.M game important in a logistic and production theme?

This is another innovation. The state of the art regarding games in production system and logistic system is undeveloped. Lewis and Maylor defined a ranking list with the number of O.M. games presented, according to O.M. content (manufacturing production control, logistic and supply chain management, etc.) (Lewis and Maylor, 2006). (Figure 1)

OM content	Total
1 Manufacturing production control (inc. inventory, EOQ, scheduling, MRP)	31
2 General manufacturing and service operations	21
3 Service quality (inc. complaint and recovery, customer care, etc.)	11
4 Logistics/supply chain management	10
5 Capacity/demand (inc. strategy, forecasting, investment appraisal)	8
6 Manufacturing quality management (inc. SPC, TQM, Kaizen)	7
7 New product development (inc concurrent engineering)	6
8 Purchasing	3
8 Just-in-time (inc. Lean Production)	3
8 Plant/product maintenance and repair	3
8 Modelling and process re-design	3
8 Supervision and workforce management (inc. leadership)	3
13 Process technology (inc. FMS and CAD/CAM)	2
14 Team working	1
14 International operations strategy	1
Total	113

Fig. 1 State of the art of O.M. games. (From: Lewis and Maylor, 2006)

In this list there are only 10 (8% of total) O.M. games in logistics, and "at least 4 of these games are variants on the classic 'beer game' developed to illustrate the Bull Whip effect" (Lewis and Maylor, 2006). This game therefore represents a significant contribution to a type of O.M. game where improvement is needed, due to its importance.

At last the possible applications of this type of game are not only for educational purposes. The paper describes its use as a tool in order to assess management capability in an assessment process.

2. Literature Review

Operation management (OM) education employs a wide variety of games (Riis and Mikkelsen, 1995), ranging from simple 'tabletop' (Robinson and Robinson, 1994) and 'red bead' experiments (Deming, 1986), to system simulations like the Beer (Forrester, 1961; Senge, 1990) and Cuppa Manufacturing games (Ammar and Wright, 1999). Moreover, we find other much more complicated interactive environments like the 'training factory' (Haapsalo and Hyvonen, 2001), or 'the supply chain trading agent competition' (Arunachalam R., Sadeh, 2004), where the game, developed using a web based application facility, requires agents to organize the assembly of PCs,

where competing for customer orders and for key components the complexity and competitive nature inherent to supply chain environments arise. Hoogeweegen et al. introduce a multi-player simulation game called Business Networking Game, which lets players experience how the trend of mass customization and product personalization changes stable business networks into dynamic networks (Hoogeweegen et al. 2004). This type of game is important not only for the actual development of games, but also for its conceptual schema, which is not only crucial to understand the educational process involved but is also a comprehensive guide to the educational content and the playing process of OM-specific games (Lewis and Maylor, 2006).
Other authors use the O.M games because they are a real setting to define new mathematical models. Strozzi et al. analyse the optimal Beer Game order policy when customers demand increases using the Genetic Algorithms (GAs) technique. Other research papers have been developed using the Beer Distribution Game (Strozzi et al. 2006). Yan Wu and Katok investigate the effect of learning and communication on the bullwhip effect in supply chains (Yan Wu and Katok 2005). Croson and Donohue report the results of an experiment, which examined whether giving supply chain partners access to downstream inventory information is more effective at reducing bullwhip behaviour, and its associated costs, rather than similar access to upstream inventory information using a controlled version of the Beer Distribution Game as the setting for our experiment (Croson and Donohue 2002). Berman and Gavious solve a leader-follower game with a facility installation problem that provide support in case of a terrorist attack, and they solve it efficiently for one facility and formulate it as a mathematical programming problem for a general number of facilities (Berman and Gavious 2005). Heuvel et al. introduce an economic lot-sizing (ELS) game in which there is a number of retailers that have a demand, which is already known, for a fixed number of periods; to satisfy this demand, the retailers order products always to the same manufacturer, thus proving that by placing joint orders instead of individual orders, costs can be reduced and a cooperative game arises (Heuvel et al. 2005).
A great difficulty in creating O.M. games is represented by the ability to define a real environment, with real and visible effects. Also the literature analysis shows a lack of games design in production and logistic as a competition in a real testable industrial environment. The innovative application of a simulation package and of a data base application, creates the elements to design a modern, useful and efficient O.M. game with the principal aim of providing experience directly to the students and the managers involved in challenging in the Logistic Game®.

3. Logistic Game®: game overview

The Logistic Game® consists in implementing, through successive steps, a set of decisions that influence the performance of the system. The environment is the modern industrial context of the LOG company. The LOG company is on the market with 2 kinds of products, product A and product B, that are producing into an inefficient plant. The initial situation is known by the teams. The actual production system is not able to respond to the market in terms of target output for each product and in terms of generated costs. For this reason, the LOG company decides to redesign the production system, but to keep the same process. This means that the type of manufacturing operations and general layout remain the same, but there is a series of decisions to be made in order to change the performance of the production system. The competition is developed in 3 successive steps.
Figure 2 shows the competition process.

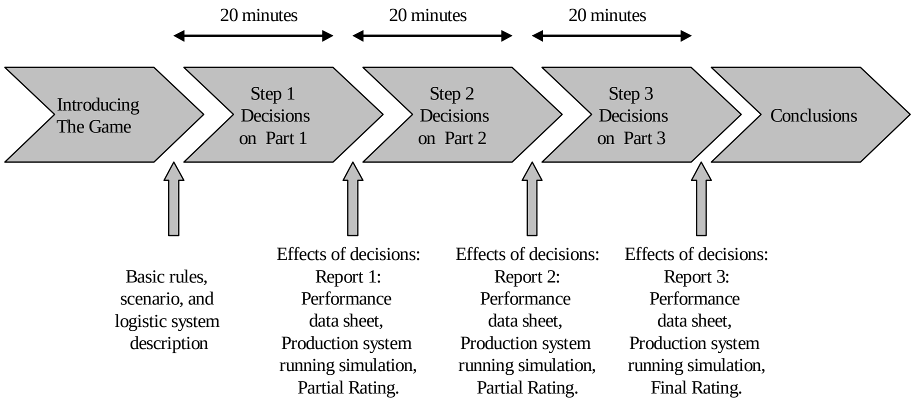

Fig.2 The competition process.

3.1 Introducing the Game

At the beginning of the competition the basic rules, the scenario and the logistic system are presented. Each team has a limited amount of financial resources and at each step has to pay for the installation decisions made. Initially a work kit is given to each team containing:

- The global layout of the production system, with all measurements in meters. (Figure 3)
- The production cycles for product A and B (Figure 4)
- The production volume target for product A and B
- The financial resources for the installation costs
- The objective of the game

The scenario of the game is the logistic production system of the LOG company that has to be modified. The production system has been developed using a simulation package: AutoMod™ . The AutoMod™ is a set of simulation tools that provides an environment for building highly accurate industrial production models for analysis and development. The game, however, is independent from the simulator in use. A friendly and useful software application in order to obtain the performance data sheet has been developed by the authors. The layout can be divided in 3 parts (Figure 3), and the decisions of the teams are taken in 3 different successive steps.
Each step of decisions corresponds to one part of the layout, with the possibility to change some previous decisions with a penalization. The decisional flow according to the layout is from the beginning (raw materials) to the end (finite products). This aspect has been chosen by the authors in order to make the game more complex and in order to create financial constraints. The second aspect is due to the more financial investment required for the installation in Part 1. The possible decisions are fixed and elicited in a "Decision Table", which varies at each step of the game. The objective of the game is to obtain the best performance of the logistic system with the minimum amount of installation costs. This is represented by an objective function.

The 3 parts of the layout for the presented logistic system are:

1. *Part 1: The mechanical manufacturing system*
2. *Part 2: The material handling device system*
3. *Part 3: The final assembly and packaging system*

Part 1: The mechanical manufacturing system

In this part products A and B are given a series of mechanical operations.
Both products are manufactured by the Work Centre 1 and 2 with batch size production.
They move through the line into pallet made up of 10 products each. After these operations product A keeps its production cycle through Work Centre 3 and 4, whereas product B does it through Work Centre 5. At this step teams have to decide the batch size of the production system and the type of Work Centres choosing between 2 possibilities, fast and slow.

Part 2: The material handling device system

In this part the pallets of product A and B, made up of 10 products each, are taken by an AGV system at the end of part 1 of the production system and are moved into the Inspect Station in which the products are controlled. The average value of the adequate products is 80%. This 80% is directly moved into the Label Station, the other 20% is moved into the Repair Station and then into the Label Station. At this stage teams have to decide the number of AGVs and the possibility to improve the performance of the 3 stations using kaizen activities.

Part 3: The final assembly system.

In this part the pallets of products A and B are moved by the AGV system into the assembly and packaging line. Product A is brought in the A line and product B in the B line. The first operator of the lines takes each product from the pallet and moves the product to the next operator who makes some assembly operations in different stations. At this stage teams have to decide the balancing of the assembly and packaging line choosing between 4 different kinds of balancing.

The game shows in this way different problems that have to be solved with an integrated approach, as it happens in the real industrial world:

Part1:

- A capacity installation problem.
- An automated line balancing problem with finite capacity of intermediate buffers.

Part2:

- An AGV net design problem.
- A kaizen application problem

Part3:

- An assembly line balancing problem.

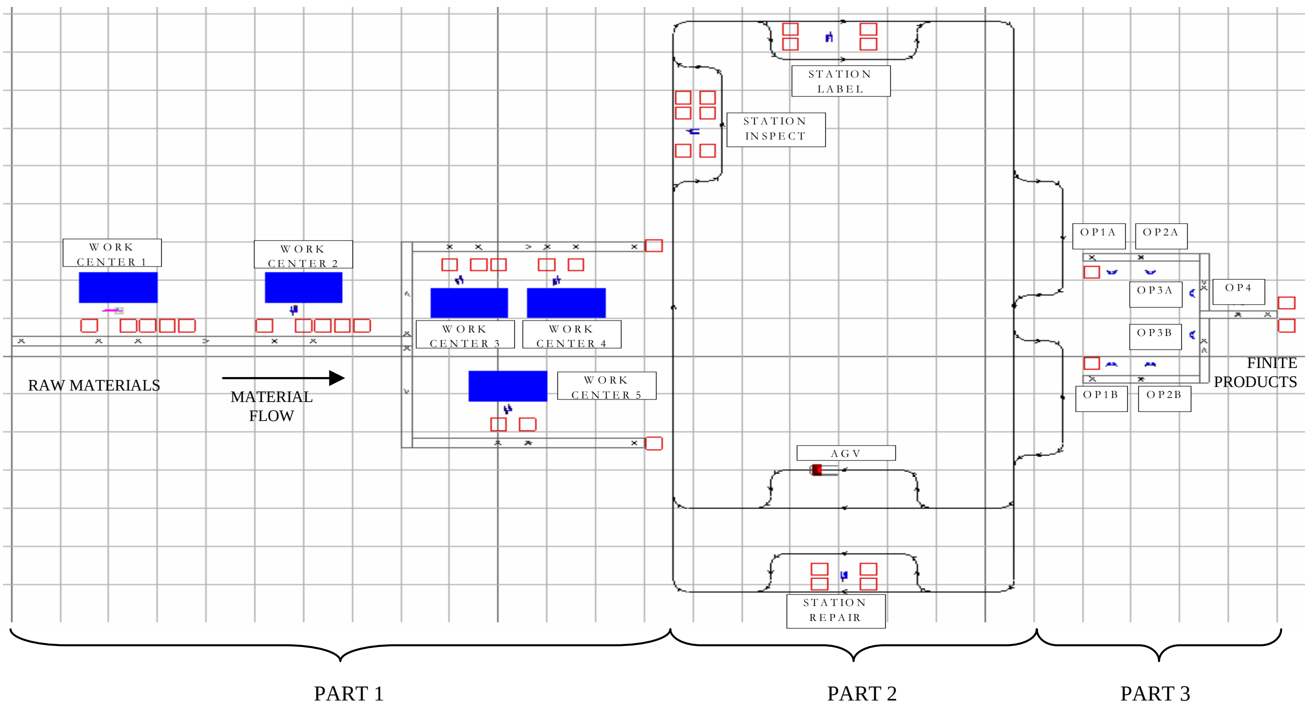

Fig.3 General layout.

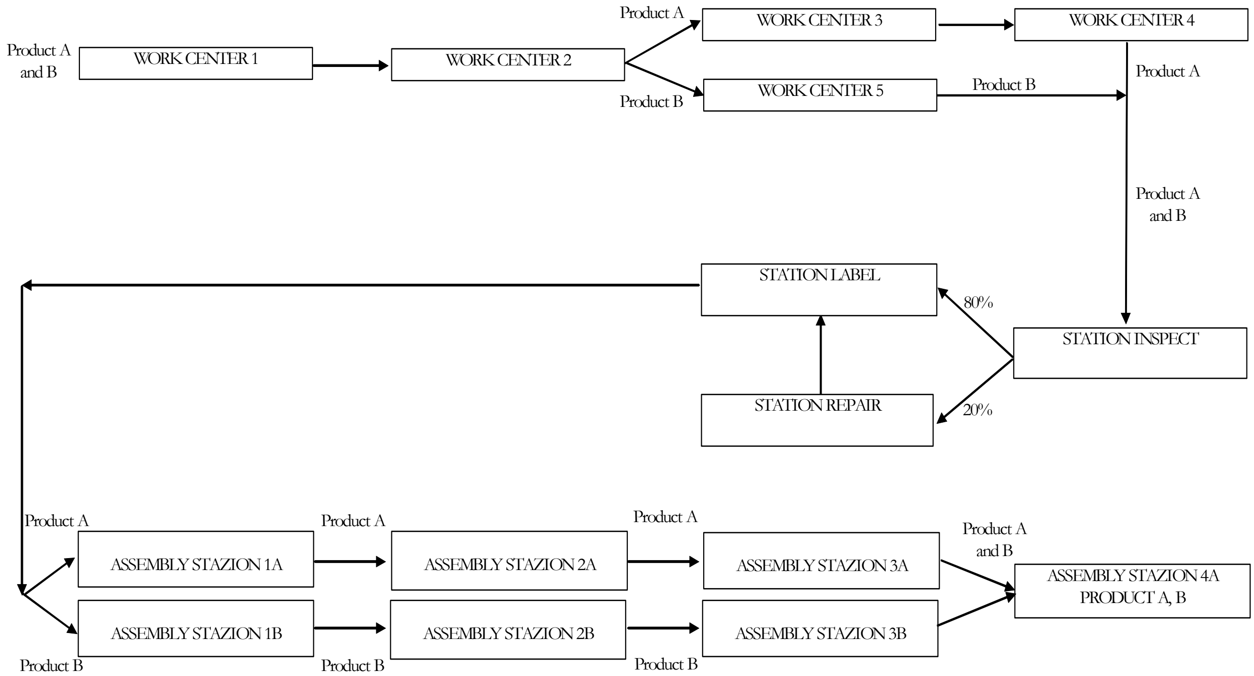

Fig.4 Production cycles of product A and B

3.2 Game steps

At each step a series of information concerning the relating part of the production system is described and given to the teams.

- Equipment data sheet about the decisions to be made (e.g. for working centres: work time for each product, availability data, setup time, quality losses rate, etc.).
- Decisions table, in which there are the possible decisions that can be taken.

Each step of the game can be conceptually divided into 5 phases (Figure 5):

1. Decision Phase. The teams define strategic decisions with team working, sharing experience, O.M. model application.
2. Mechanic Phase 1. Teams deliver the strategic decisions to the game administration.
3. Mechanic Phase 2. Teams obtain a performance data sheet of the system.
4. Mechanic Phase 3. Teams view the production system running using simulation.
5. Analytical Phase. Teams discuss the results of each step, the partial ranking and try to understand the possible changes in strategic decisions for the next step.

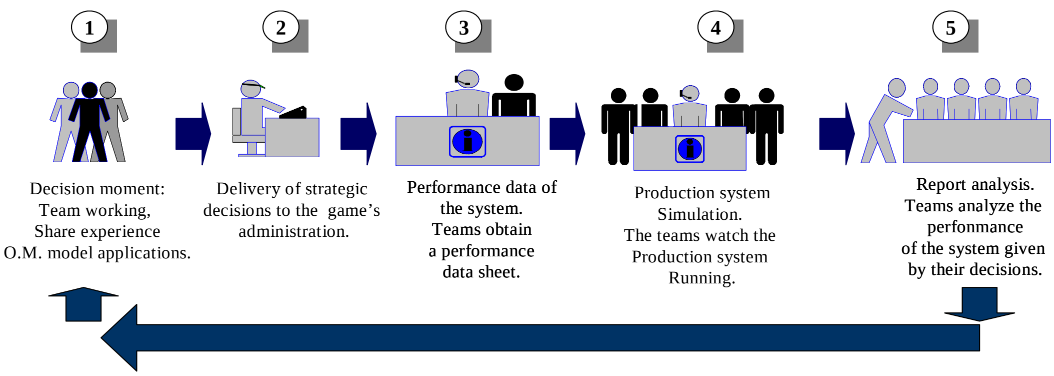

Fig. 5 Phases of Logistic Game®

The performance data sheet includes data on:

- Investment costs due to the decisions that have been made
- Production volume for products A and B of the system
- Utilization rate of the installed resources
- WIP data in the system
- Queue time before each resource

An instant of the logistic system "running", is shown in Figure 6. The two different kinds of products A and B and their production cycles can be noted.

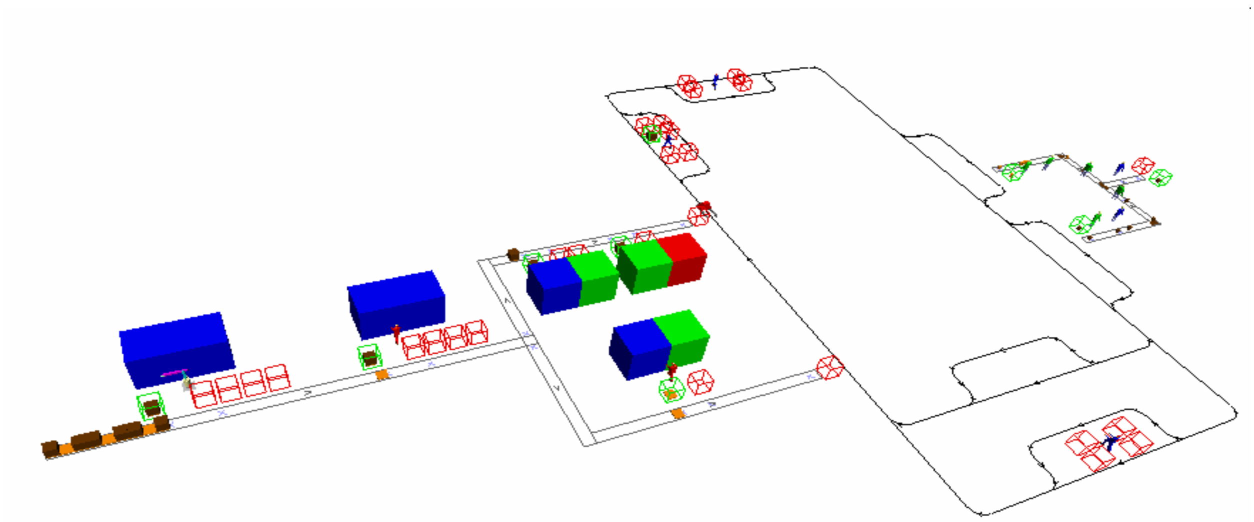

Fig. 6 Logistic system "running".

In this way at the end of each phase every team has a series of information. Thus having a decisional process with a large amount of input data (some crucial, some other less important). In order to study the behaviour of the teams during the game and to schematize the decisional process, the Input-Process-Output model developed by Lewis and Maylor in 2006 is used. (Figure 7).

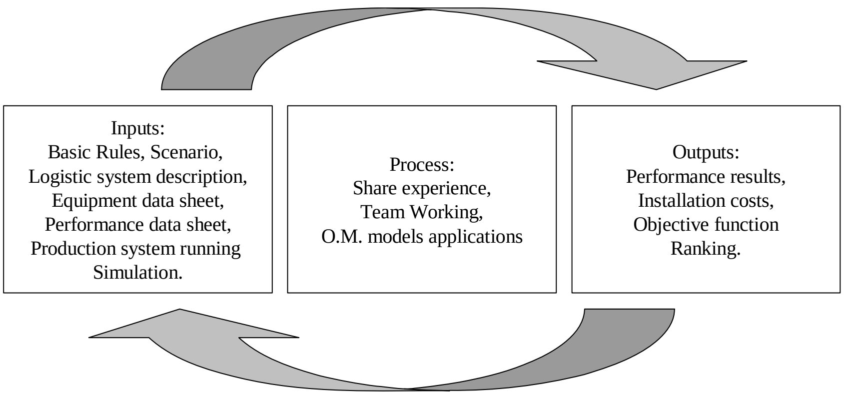

Fig. 7 Input-process-Output Model for Logistic Game®

The decisional process is an iterative process in which at each step teams gain experience, share it with others and, using the available and large input data, elaborate strategic decisions and apply the O.M. models to a dynamic context. This is a challenging issue. Many O.M. models (for example the design of an AGV system) are "static" and do not consider dynamic aspects. This game, instead, differs from the rest for reproducing a logistic system, which takes all dynamic aspects into account, thus being highly educative.

3.4 Conclusions

At the end of the game the final ranking is presented. The right decisions are revealed and it is explained why the others were wrong. The best solution is shown with the simulator and the most common mistakes made by the teams during the competition are explained and discussed. The aim here is therefore both to explain the application of the O.M. model and to educate.

3.5 The Objective Function

The objective of the game is to obtain the best performance of the logistic system with the minimum amount of installation costs. This is represented by an objective function.
Each decision generates a cost. There are installation costs due to the chosen equipment, but also working costs, due to the running of the system.
The installation costs depend on the equipment. Decision taken during the first step are only for Part 1 of the system. In the successive steps it is possible to change the previous decisions by paying a penalization. The installation costs sustained in the previous step are sunk costs.
Working costs are due to the performance of the system. The better the production system performs, the less relevant working costs will be, in other words, the system needs to respond as efficiently as possible to the market demand given by the target volume in order to reduce costs.

Index
i: Decision index in Step 1, $i=1,\ldots, I$. I are the number of the decisions to take in Step 1.
j: Decision index in Step 2, $j=1,\ldots, J$. J are the number of the decisions for Step 2.
k: Decision index in Step 3, $k=1,\ldots, K$. K are the number of the decisions for Step 3.
d: Alternative index for a generic decision. It assumes value depending on the decision index:
$d=1,\ldots, d(i)$ for Step 1
$d=1,\ldots, d(j)$ for Step 2
$d=1,\ldots, d(k)$ for Step 3

Decision Variables:
$X1_{i,d}$: Decision Variable in Step 1. For a fixed i $X1_{i,d}$ =1 for the d chosen, 0 Otherwise.
$X2_{j,d}$ *:* Decision Variable in Step 2. For a fixed i $X2_{j,d}$ =1 for the d chosen, 0 Otherwise.
$X3_{k,d}$: Decision Variable in Step 3. For a fixed i $X3_{k,d}$ =1 for the d chosen, 0 Otherwise.

Input Data:
$C1_{i,d}$: Cost for the alternative d chosen for decision i in Step 1. [€/year]
$C2_{j,d}$: Cost for the alternative d chosen for decision i in Step 2. [€/year]
$C3_{k,d}$: Cost for the alternative d chosen for decision i in Step 3. [€/year]
$Q_{WIP,A}$: Quantity WIP of product A in the production system [€/year]
$Q_{WIP,B}$: Quantity WIP of product A in the production system [€/year]
Q_A : Quantity of product A produced into the production system. Data given by data base application. [pieces/year]
Q_B : Quantity of product B produced into the production system. Data given by data base application. [pieces/year]

$Q_{ATarget}$: Quantity target of product A [pieces/year]

$Q_{BTarget}$: Quantity target of product B [pieces/year]

$\Delta_A = Q_A - Q_{ATarget}$: Delta production for product A (1) [pieces/year]

$\Delta_B = Q_B - Q_{BTarget}$: Delta production for product B (2) [pieces/year]

C_A : Cost of product A [€/piece]

C_B : Cost of product B [€/piece]

$i_{\Delta PROD}$: Inventory cost rate for delta production

i_{WIP} : Inventory cost rate for WIP

$C_{\Delta Production,A} = \Delta_A \cdot C_A \cdot i_{\Delta PROD}$: Cost for product A of delta production between the quantity produced and the quantity target (3) [€/year]

$C_{\Delta Production,B} = \Delta_B \cdot C_B \cdot i_{\Delta PROD}$: Cost for product B of delta production between the quantity produced and the quantity target (4) [€/year]

$C_{Overpr,A} = \begin{cases} C_{\Delta Production,A}, if > 0 \\ 0, if \leq 0 \end{cases}$: Overproduction cost for product A, due to the cost generated by the quantity of products that are more than the target volume (5) [€/year]

$C_{Overpr,B} = \begin{cases} C_{\Delta Production,B}, if > 0 \\ 0, if \leq 0 \end{cases}$: Overproduction cost for product B, due to the cost generated by the quantity of products that are more than the target volume (6) [€/year]

$C_{Backlog,A} = \begin{cases} -C_{\Delta Production,A}, if < 0 \\ 0, if \geq 0 \end{cases}$: Backlog cost for product A, due to the cost generated by the quantity of produced products that is less than the target volume (7) [€/year]

$C_{Backlog,B} = \begin{cases} -C_{\Delta Production,B}, if < 0 \\ 0, if \geq 0 \end{cases}$: Backlog cost for product B, due to the cost generated by the quantity of produced products that is less than the target volume (8) [€/year]

$WIP_{MECCpart}$: Quantity of products A and B Work In Progress in mechanical manufacturing operations part. Data given by data base application. [pieces/year]

$WIP_{AGVpart}$: Quantity of products A and B Work In Progress in AGV part. Data given by data base application. [pieces/year]

$WIP_{ASS-PACKpart}$. Quantity of products A and B Work In Progress in the assembly and packaging line part. Data given by data base application. [pieces/year]

Objective Function:

In this way the winning team will be the one that minimize the *Total Cost Function (TCF)*:

$$TCF = C_{Inst} + C_{Overpr} + C_{Backlog} + C_{Wip} \qquad (9) \qquad [€/year]$$

Where:

C_{Inst} : Installation cost, including all costs for installation of the production system. [€/year]

C_{Overpr} *:* Total backlog cost due to the cost generated by the quantity of produced products that is less than the target volume. [€/year]

$C_{Back\log}$: Total backlog cost due to the cost generated by the quantity of produced products that is less than the target volume. [€/year]
C_{Wip}: Total Work in Progress cost, due to the inventory stocks created along the production system. [€/year]

At each step teams deliver a decisions table to the Administration of the Game. An example is shown in Figure 8 for step 1.

Batch Size	Choice 1	Choice 2	Cost Choice 1	Cost Choice 2
			[€/year]	[€/year]
Product A Batch Size	2	6	/	/
Product B Batch Size	1	3	/	/
Work Center type				
Work Center 1	Fast	Slow	92000	67000
Work Center 2	Fast	Slow	14000	10000
Work Center 3	Fast	Slow	20000	12000
Work Center 4	Fast	Slow	11000	7000
Work Center 5	Fast	Slow	22000	13000

Fig.8 Step 1 Decisions Table

The 4 addenda of the formula (1) are:

$$1)\, C_{Inst} = \begin{cases} \sum_{i=1}^{I}\sum_{d=1}^{d(i)} X1_{i,d} \cdot C1_{i,d}, Step1 \\ \sum_{j=1}^{J}\sum_{d=1}^{d(j)} X2_{j,d} \cdot C2_{j,d}, Step2 \\ \sum_{k=1}^{K}\sum_{d(1)}^{d(k)} X3_{k,d} \cdot C3_{k,d}, Step3 \end{cases} \qquad (10) \qquad [€/year]$$

2) $C_{Overpr} = C_{Overpr,A} + C_{Overpr,B}$ [€/year]
Total over production cost due to the cost generated by the quantity of products that are more than the target volume.

3) $C_{Back\log} = C_{Back\log,A} + C_{Back\log,B}$ [€/year]
Total backlog cost due to the cost generated by the quantity of produced products that is less than the target volume.

4) $C_{Wip} = Q_{WIP,A} \cdot C_A \cdot i_{WIP} + Q_{WIP,B} \cdot Q_B \cdot i_{WIP}$ [€/year]
Total WIP cost due to the average WIP presented in the production system.

6. Logistic Game®: application case in “Incontro Aziende-Studenti 2006”

On 1st December 2007 a meeting between companies and students took place in Vicenza. For the occasion a Logistic Game® competition was held where eight teams made up of 10 members each -9 engineering graduates led by a company logistic manager- challenged one another. The aim of this event was to test this innovative game as a operation management education and selection tool.

Both the students and the managers that took part in the competition really enjoyed the event, the design of the game and its purpose. On this occasion logistic managers had the possibility to share their experience with the students and at the same time to assess their skills in a real logistic context. The competition was won by Team number 8, that got very close to the optimal solution. Figure 9 shows the final results and the corresponding costs. At the end of the game the optimal solution and the most common mistakes were shown and discussed by the teams.

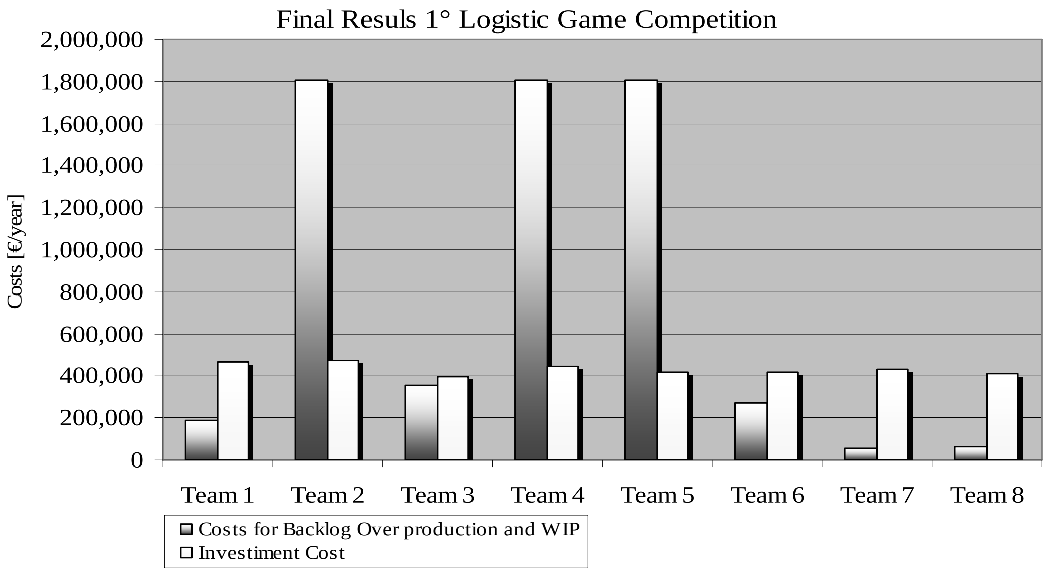

Fig.9 Final Results 1st Logistic Game Competition in "Incontro Aziende-Studenti 2006 (Becoming Manager 2006)"

Figures 10,11 shows different teams at work, where is possible to see managers and students together; figure 12 instead deals with the end of the first step when every team is called for analysing the run of the model designed.

Fig.10 Teams at work "Incontro Aziende-Studenti 2006 (Becoming Manager 2006)"

Fig.11 Discussion about the performances of the model designed "Incontro Aziende-Studenti 2006 (Becoming Manager 2006)"

7. Conclusions

The literature analysis shows a large selection of O.M games, but a real lack of games in Logistic content. There is, however, a great necessity to have "learning by doing and by applying" tools in engineering courses, in order to build up experience. To make it possible, the games must be "real" or, in other words, represents the real production and logistic system. The degree of complexity and integration between different "sub-systems" and its dynamic aspects make the whole simulation a real decision making problem. The innovative application of the simulation and the use of the particular data base application developed by the authors give these features to the Logistic Game®. Moreover, the application case shows the educational power and other possible applications of O.M. games, and in particular how the new innovative Logistic Game® developed.
Logistic Game® is recently used with success in a new event "JADE 2007 MEETING" where the game is carried out between ten industrial teams formed by student of ten European Universities.

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