

A MULTIDIMENSIONAL TOURISM CARRYING CAPACITY MODEL: AN EMPIRICAL APPROACH

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ABSTRACT

It is often observed that tourism generates a negative impact on the environment of destination places, among which the depletion of the natural capital is the most evident. To avoid this, tourism development and management should be based on the recognition of the limits characterising a destination. The indicator of Tourism Carrying Capacity (TCC) can be particularly relevant to this purpose. In fact, it gives an idea of the threshold of tourists that can be accepted at a destination while considering the capacities of some components of the local tourism system. In this work, we approach a specific definition of TCC, and for its empirical measurement, we also develop a multidimensional model in the form of a mathematical programming application. Furthermore, we apply the model to some tourism destinations in the area of the Gargano National Park (South Italy), where evidence of unsustainable tourism management can be observed.

1. INTRODUCTION

Tourism represents one of the most important activities in world trade. Figures from the World Tourism Organisation show how it has grown rapidly over the past 30 years and still shows trends of further exponential growth. As a result, governments see the tourism sector as an important element in stimulating their local and regional economies. In fact, as stressed by Johnson (1999) tourism flows constitute a powerful tool by which it is possible to transfer resources both within a country and across its borders. However, it is broadly claimed that much of this growth is very often unsustainable under both an environmental and a social point of view. Numerous examples of damage caused by this very rapid growth, particularly in those areas characterised by poverty among the local population and fragile natural environment, are extensively referred to in the specific literature (e.g. Mathieson & Wall, 1982; Ryan, 1991). Hence, as Burns and Holden (1995) observe contrary to what is nowadays said, it does not appear that modern forms of tourism are fully capable of generating less impact on the environment of destination places. Even in those areas where more environmentally friendly forms of tourism management are implemented – by gradually moving from mass to eco or green forms – environmental disruption can occur.

If we pay attention to appropriate definitions of tourism we can gain some key ideas of the main features it assumes. Following Pearce (1991) it is possible to learn that there is general agreement to consider any form of tourism as a *multi-faceted* and *geographically complex* activity. In other terms, it is seen in the same way as an “engine” which is able to send impulses to different activity sectors of territorially specified economies, while at the same time generating negative impacts. Indeed, further to the generation of benefits – mainly related to the possibility of local economic development arising from the growth of the tourism sector and the expansion of its large range of surrounding activities – negative aspects associated with modifications of the local environment of destination places must also be considered. These modifications are usually related to land space use, which very often generates uncontrolled exploitation of the local environment in its broadest sense. It is unavoidable that tourism consumes materials and energy, produces waste in origin, transit, and destination areas, while effecting the local social sphere. After all, the practice of tourism activities at destinations can be divided into two categories: those promoted by the tourism industry to develop attractive products and those practised by tourists, who use facilities and the local setting in many different ways.

A further definition of tourism can be found in a work by Jensen-Verbeke (1993: 212) who states that it is “... the temporary movement of people to destinations outside their normal place of work and residence, the activities taken during their stay in those destinations and the facilities created to cater for their needs”. Once again, tourism as a major industry is viewed in the same light as a manufacturing one, with respect to its capability of generating economic benefits, while at the same time generating modifications in the local environment among which the exploitation and pollution of the natural environment are only the most evident consequences.

Hence, a complex and often controversial interaction exists between tourism and the local environment. This is mirrored in a sort of fluctuant dynamic, particularly in the relation between tourism and natural capital, which has been stigmatised in a description by Butler (1980). The same interaction would be observable even in the case of more eco-compatible configurations of tourism since they are always based on the use of assets, which are mainly represented by public goods and global heritage. Although some might say that most of these resources are renewable, it can be appropriately argued that, if they are put under too much stress, they might collapse. As a result, they turn into non-renewable resources because their regeneration capacity has been compromised. This consciousness calls for their preservation with the aim of ensuring not only a long-run growth of tourism activities but also a certain level of well-being among the local communities. Hence, an effort must be made to identify and implement tools and management strategies for the rational use of tourism resources so that their depletion can be avoided. With regard to this, the TCC can be considered as a cornerstone for a rational use of tourism resources. In fact, it helps to identify thresholds of the maximum tourist acceptance at a given destination. Recent work has criticised the concept of carrying capacity and particularly the search for a numerical based measure of TCC, listing among its limitations its lack of consideration of the social and biophysical aspects of tourism development and management (McCool & Lime, 2001). Nevertheless, the identification of a numerical measure of TCC is still and broadly considered as a useful tool available to tourism planners and managers in determining an indication of the acceptable use level of a tourism area, intended as a subsystem of a larger territorial system. The indication could be more valid if the sought numerical measure is the result of multidimensional TCC models. As some authors highlight, multidimensional TCC models could allow us to achieve results to help satisfy our informative need, since it would give us the possibility of simultaneously paying attention to economic, social, biophysical and political dimensions of any complex planning or management decision (Clayton, 2002). According to this view, we do believe that in tourism planning this indicator is of a crucial importance and a certain amount of attention should be paid to it. Nevertheless, the specific literature refers to a few experiences where the effort of identifying an empirical method for the TCC computation has been made. In fact, although the specific literature on the carrying capacity and TCC is widely developed, many scientific readings present the issue in question as a theoretical discussion which risks taking us to a no-end debate rather than empirical applications.

Having said this, the aim of this work is to identify a meaningful definition of TCC through which the identification and the empirical application of a TCC model can become practical pathways and not just a theoretical or oratory exercise. To this purpose, the relationship existing between tourism and the local environment, with particular regard to the natural capital, will be firstly put into evidence. At the same stage, the concept of TCC will be introduced and successively investigated in more detail. With regard to this, a TCC model will be built and empirically applied to some tourism destinations in the Gargano National Park (South Italy). Finally, some general conclusions will be drawn on the subject.

2. TOURISM DEVELOPMENT AND THE NATURAL ENVIRONMENT

As we have already mentioned in the previous section, the fluctuating relationship between tourism development and the natural environment is simply described by referring to Butler's work (1980). Firstly, the natural environment of a specific place attracts tourism because of its peculiarities. As the place becomes more popular among tourists and develops into an important tourist destination, the natural environment suffers from either more or less deep transformation due to the growing tourist presence. It is clear that in such a situation if tourism flows are badly managed and oriented then the destruction of the place in question will inevitably be the final result. As a consequence, this will transmit a feedback to the tourism market in terms of attractive potential loss and tourism flows will end in a short timeframe. The destruction of tourism resources will negatively affect both the local population and the future generations of tourists. While the former will see their future prospects of revenues compromised, the latter will not have the possibility of experiencing a different environment

from the one in which they live. In other words, the natural environment is viewed as the initial element in attracting tourism flows, and as a result the first element to suffer from negative impacts arising from an increase in tourism flows. Several studies have highlighted the negative effects caused by tourism on the environment of destinations due to the fact that it inevitably leads to the transformation of the host community (e.g. Burns & Holden, 1995; France, 1997; Mathieson & Wall, 1982; Ryan, 1991). Table 1 below reports a basic synthesis of the main advantages and disadvantages occurring to tourism destination places as a result of the tourism activity.

Tab. 1 – Main environmental impacts of tourism

| Advantages | Disadvantages |
|---|--|
| 1. conservation of natural areas and wildlife; | 1. seasonal effects on population densities and structures, landscape change (permanent environmental restructuring), loss of aesthetic value; |
| 2. environmental appreciation; | 2. energy costs of transport, noise, air pollution, water pollution and generation of waste; |
| 3. rehabilitation and often also transformation of old buildings and sites into new facilities; | 3. deforestation, impacts on vegetation through the collection of flowers and bulbs; |
| 4. introduction of planning and management. | 4. disruption of animal breeding patterns and habits; |
| | 5. destruction of beaches, dunes, coral reefs, many national parks and wilderness areas through trampling and/or the use of vehicles. |

Source: Cater (1997).

From the picture we have drawn, it would be natural to say that in the tourism context the implementation of the ecologist's thinking, that is the application of a strong sustainability idea to preserve biodiversity and the entire natural environment, would be deemed more appropriate. Indeed, as highlighted by Pearce *et al.* (1989 and 1990) the idea of strong sustainability is strictly associated with environmental protection, which would mean to provide a non-declining natural capital stock over time. In other terms, referring to a work by Collins (1999: 100), it may be said that at a given destination, to gain *sustainability* the following condition would be required:

$$\partial(K_{nj} / N_j) / \partial T \geq 0 \quad (1)$$

This means that the variation of the per capita endowment of natural capital (K_n/N) in the considered destination (j) over time (T) should be positive or at least equal to zero. Since tourism activities are unavoidably based on degrading natural capital actions, the above condition would be satisfied only in the case a certain degree of substitutability between natural capital and manmade capital is accepted. In such a way the destruction of natural capital could be compensated by reconstructing, transplanting or restoring the affected natural assets at a considered destination. As it can be easily realised, the implementation of such a proposal would be difficult, since the “green” or “environmentalist” thinking retains that the natural capital should be preserved as it is typically unique and holds no substitutable features. In a tourism context this would mean that environmental protection policies – due to them requiring environmental assets to remain untouched – could represent a constraining condition to the economic development of communities living in those areas characterised by an evident vocation to tourism. In fact, they would see the only possibility of using their territories to gain economic revenues denied.

A concrete approach to the management of these two extremes would be to assess time to time the priorities and needs of a given place and its local population. In simpler words, we should begin a process of evaluation which can be summarised in the following few questions. What is the first interest we should satisfy? Should we pay more attention to protecting the natural assets and at the same time foregoing economic development opportunities? Or should we give high priority to the satisfaction of the actual human needs of building on economic development and depleting natural assets? Realistically thinking, we should answer the final question positively and guarantee a responsible approach of resources management by minimising the negative impact arising from running the development. If we agree that tourism activities are resource-based, the identification of an indicator for the level of tourist resource use would surely be a key parameter for implementing

suitable tools in planning and resources management. With regard to these aspects, a central role can be played by indicators of tourism sustainability and, among these, that represented by the TCC. As anticipated, this indicator can provide for measures representing critical thresholds that, if overtaken, give the idea that the tourism development and/or management in a destination area is on an unsustainable path. As a consequence, the risk of generating environmental stress and damage and reducing the natural capital stock is very likely.

Broadly speaking and referring to Steele's words (1995: 32), this indicator can be intended as "the amount of tourism damage a site can assimilate without long term damage which can be measured against the total number of tourists using the site to determine the social optimum has been exceeded and the site is being over-utilised". However, it must be made clear that the concept of damage can assume different forms so that the indicator in question can be intended in several ways. Indeed, it can be based on ecological, physical, social and psychological constraints. Although the existence of a certain interaction between these constraints is generally recognised, it is also believed that primacy should be recognised to the ecological one in order to ensure the satisfaction of at least the constant stock of natural capital which is clearly expressed by the earlier equation (1).

3. CONCEPTUALISING FOR MEASURING THE TCC

Our aim in this section is to find a consistent way of empirically applying the TCC. Before doing this and with the aim of giving a clearer idea of the meaning of the carrying capacity and TCC concepts, we will firstly give a very short theoretical review. Afterwards, we will enter into a more technical treatment of the issue by identifying some analysis tools which allow us to set up a possible multidimensional model for the empirical estimation of TCC.

The carrying capacity concept comes from biological and ecological sciences, where it was first developed to mean the upper population level of a particular species which can be supported in a given area. In other words, the carrying capacity identifies an upper level or saturation point and, once it has been reached, the species population is at its maximum sustainable level. However, to the aim of applying a concept of saturation point to human populations some complications should be added. In fact, particularly Atkinson *et al.* (1997: 120) stress how not only the population level but also its economic activities should be considered. Hence, to the aim of developing this indicator some simplifying assumptions must be made. The interest in applying the carrying capacity concept to identify environmental limits generated by human activities started in the early 1970's and since then several modifications of the concept have occurred. It soon became clear that the concept is influenced by value-judgements and institutional settings. As it has been noted by Seidl and Tisdell (1999: 402), these are the two components which affect not only the decision of limit or carrying capacity but also the judgement of a certain environmental situation. For this reason, the carrying capacity concept does not have a single meaning since its understanding depends on the pursued aims.

As can be expected, even in the tourism field many different definitions of carrying capacity have been produced which have often led to equivocal applications. One of the earlier definitions of TCC refers to the maximum number of visitors that can be tolerated without irreversible or unacceptable deterioration of the physical environment and without considerably diminishing user satisfaction. With regard to this, authors such as Seidl and Tisdell (1999), in agreement with what is also discussed by Mathieson and Wall (1982), have adequately highlighted the difficulty of determining a maximum visitor number since each of the economic, physical-environmental and social subsystems of relevance hold different and separate capacities. For this reason, some authors underline that a TCC measure, which is based on the simple search of the tourist use levels or the number of visitors, may involve a misguided simplicity, while instead a focus on general site conditions is advocated (Garrod & Fyall, 1998; Lindberg *et al.*, 1997; McCool & Lime, 2001). From what we have reported so far, it is possible to see how the evolution of the TCC has generated two different ways of interpreting it. Firstly, the solution for achieving a measure of TCC was sought in placing a limit on the number of users allowed to access a resource at or below the level at which they would create irreparable damage to the

resource. Secondly, the concept of carrying capacity moves from what we have just said to one finding the optimal number of visitors, the management of resources, the users expectations and preferences, and physical parameters of the resources (Boyd & Butler, 1986; Clayton, 2002). In other words, the implications of this second approach to the idea of TCC are mainly related to the fact that setting limits on the number of users is of little value unless they are placed in the context of resource management objectives. This idea could be put into practice by using a multidimensional TCC model.

With regard to this last consideration, a very interesting approach for the empirical application of the TCC in situations where tourism pressure also involves urban environments is suggested in a work by Canestrelli and Costa (1991). They refer to Fisher and Krutilla's criterion to reach a practicable definition of carrying capacity with an emphasis on the idea of sustained yield, underlining how it can be referred to both ecological/biophysical and economic terms. The first refers to the maximum number of visitors that can be accommodated in maximum stress conditions. The latter refers to the maximum number of visitors that can be accommodated at a constant quality of their experience. Furthermore, in such a context, the carrying capacity would come to represent the upper limit of the potential visitor number in a resource-based tourism destination. Indeed, as they observe, any considered tourism destination is constrained by the capacity of a given set of supporting subsystems (e.g. facilities set up to fulfil the visitors' needs such as hotels, parking places, etc.) to which it is unavoidably related. On such a basis, the problem becomes that of finding a use level of the resource-based tourism destination which does not violate any constraint fixed by the considered supporting subsystems.¹ Put in this way, the aim is to determine the optimal use level of a resource-based tourism destination achievable by solving a maximization problem which can be formally presented as follows:

$$\max \quad \pi(q) = B(q) - C(q) \quad (2)$$

with

$$C(q) = C_d(q) + C_m(q) + C_k(q) \quad (3)$$

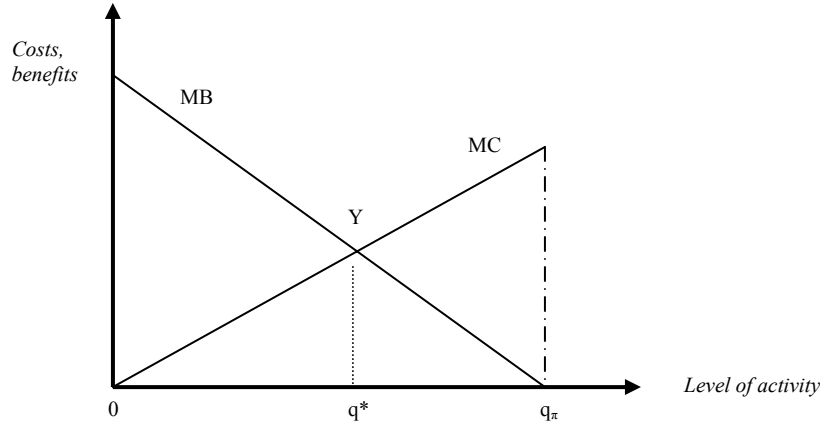
where π represents the amount of net benefits from the activity; B refers to gross benefits; C is the amount of costs implied to run the activity; q is the use level of the recreation attraction; C_d is the cost of ecological environment damage; C_m represents the amount of current expenditures; C_k is the capital expenditures (e.g., the relevant interest and depreciation charges). This problem finds its solution by differentiating the equation with respect to q and setting equal to zero:

$$\frac{\partial \pi}{\partial q} = \frac{\partial B}{\partial q} - \frac{\partial C_d}{\partial q} - \frac{\partial C_m}{\partial q} - \frac{\partial C_k}{\partial q} = 0 \quad (4)$$

The optimum use level q^* of the resource will be found, as the graph in the following figure 1 shows, at the point between the highest (where benefits are at the maximum) and the lowest (where costs are at the minimum) use levels.

¹ At this point, one can argue that growing use levels can be easily faced by enlarging the capacity of the supporting subsystems. However, it must not be forgotten that their expansion is not always socially desirable. In fact, two opposite positions can be observed with regard to the subsystem expanding hypothesis. On the one hand, that part of local population which is involved in tourism related activities will surely agree since they will gain more benefits. On the other hand, this kind of action may be seen by the local resident population (not involved in tourism activities) as generating negative impacts (costs) on economic, physical and social spheres of the environment, clearly resulting in their objection, which would represent a further limiting factor. It is easy to understand how the prevailing view of these two different positions is the result of a democratic voting system and through which the local communities decide for their representatives.

Fig. 1 – Optimal use of a recreation resource



In agreement with what Canestrelli and Costa (1991: 297-230) observe and argue, this could be a practical approach to empirically determining a measure of carrying capacity for tourism destinations. However, what we would like to highlight is that this approach gives us the possibility of building a multidimensional model which can be brought to a solution by converting the problem into a linear programming (LP) one.

4. A LP MODEL FOR THE COMPUTATION OF MULTIDIMENSIONAL TCC

As Hazell and Norton (1986) report, linear programming (LP) is a mathematical method of determining the optimal allocation of scarce resources among competing activities or products. In fact, its procedure maximizes profits (or minimizes costs) which can be generated by a combination of activities or products, that is feasible with respect to a set of fixed resource constraints. Hence, for a given activity sector, a linear programming model requires the specification of the following elements: ❶ the alternative sector activities, their unit of measurement, their resource requirements, and any specific constraints on their production; ❷ the fixed resource constraints the sector faces; ❸ the forecast activity returns net of the variable costs (gross margins). In more formal terms, following Chiang's model, (1984), the formulation of a linear programming model for a maximization case can be written as follows:

$$\max Z = \sum_{j=1}^n c_j X_j \quad (5)$$

such that

$$\sum_{j=1}^n a_{ij} X_j \leq r_i \quad (i = 1 \text{ to } m) \quad (6)$$

and

$$X_j \geq 0 \quad (j = 1 \text{ to } n) \quad (7)$$

where X_j is the level of the j^{th} sector activity (e.g., in our case we will have hotel tourism and non-hotel tourism activities), with $j = 1$ to n denoting the number of possible activities; c_j is the forecasted gross margin of a unit of the j^{th} activity; a_{ij} represents the quantity of the i^{th} resource required/used to produce/generate one unit of j^{th} activity, with $i = 1$ to m denoting the number of resources; r_i is the amount of the i^{th} resource available (which represents the constraint). In other words, the problem presented by such a model, which is known as the primal linear programming problem, is to find a plan sector (defined by a set of activity levels X_j , $j = 1$ to n) that generates the highest level of total

gross margin Z without either breaking any of the fixed resource constraints (represented by the equation 6) or involving any negative activity levels (represented by the equation 7).

The solution to LP problems can be found by using the *simplex* method, whose key is to reduce the feasible sector plans that need to be considered to a finite number identified with the name of basic solutions. To do this, the *simplex method* introduces the notion of slack activities which permit to convert all inequality constraints into equalities. In fact, if we want to transform an inequality constraint considered by equation (6) into an equality constraint, then we can write

$$\sum_j a_{ij} X_j + S_i = r_i \quad (8)$$

where S_i is known as the slack activity representing the amount of the i^{th} resource not used in the sector plan. Very powerful computer software exists to mechanise this transformation and search for the optimal solution.

Having made this technical premise, we now move onto determining the TCC as an optimal use level – that is the point where benefits are maximized and cost minimized – for three municipalities representing the most important tourism destinations in the area of the Gargano National Park: *Manfredonia*, *San Giovanni Rotondo* and *Vieste*. To the aim of setting the LP model for these places, we argue as follows. Firstly, five supporting facilities are considered as relevant to fulfil the basic needs of the tourist. These are mainly represented by aspects related to accommodation needs together with some early proxy of their biophysical impact on the hosting territory (beds in the hotel and non-hotel sectors, solid waste and sewage disposal). In addition, tourist parking requirement (number of parking spaces available is also considered). Secondly, two types of visitor are identified as requiring services from the local tourism sector: those who use hotel services, so called hotel tourists (HT), and those who use non-hotel services, so called non-hotel tourists (NHT), whose interest is more oriented to camping areas and tourism villages. Considering what we have just said, the objective function of our linear programming model can be expressed in the following terms:

$$\max_{HT, NHT} \quad \pi = (p_{HT} - c_{HT})HT + (p_{NHT} - c_{NHT})NHT \quad (9)$$

where π represents the net private benefits from the whole tourism sector; HT and NHT are the number of tourists identified in each of the two groups we are considering, that is hotel and non-hotel tourists respectively; p_{HT} and p_{NHT} represent the per night price averages in the hotel and non-hotel sectors respectively; c_{HT} and c_{NHT} refer to the daily cost borne by the hotel/non-hotel management per each group of tourist. Moving now onto describing the constraints of the objective function, we can summarise as follows:

1. HB = number of beds available in the hotel sector;
2. NHB = number of beds available in the non-hotel sector;
3. GD = waste disposal capacity (in kg./day);
4. SD = sewage disposal capacity (in mc./day);
5. PP = number of car and coach parking places.

On the basis of this model formulation, empirical applications can be carried out². This will be the purpose of the next section.

² It is clear that the number of constraints in the model could be enlarged to take into consideration, where it is the case, other aspects which are more specifically related to social and/or biophysical issues. Of course, this would require valid information on functional forms which can significantly describe and explain the relationships existing between tourists and both the social and biophysical spheres of the host communities.

5. TCC MODEL CALIBRATIONS AND SOLUTIONS

We can now move onto calibrating our LP model for obtaining solutions of the TCC for each of the three considered municipalities. As we have already commented, the coefficients of the variables in the objective function are the average of the net benefit (in Euros) obtainable from an individual belonging to each of the two tourist categories we have taken into account. We will note that different values are set as coefficients in the objective functions for each considered tourism destination. This is due, of course, to the differences in bed-night prices and hotel/non-hotel management costs existing in the three municipalities. Data on bed-night prices are from the records of the local tourism office Azienda di Promozione Turistica della provincia di Foggia (A.P.T.) and refers to the year 2002. Information on the management costs borne in both the hotel and non-hotel sectors have been obtained by interviewing local tourism operators, and in particular a representative of the UNIOPTURISMO, which is one of the main tourism operator corporations locally present.

With regard to the number of beds in the hotel sector, official statistics provided by the local A.P.T. show 992 beds in *Manfredonia*, 3,679 in *San Giovanni Rotondo* and 3,980 in *Vieste*. With the aim of setting the constraint related to the use of this resource, it is evident that beds in the hotel sector can be requested by hotel tourists only. Hence, a coefficient equal to 1 is assigned to them, while 0 to the non-hotel tourists. The non-hotel sector offers 2,166 beds in *Manfredonia*, 852 in *San Giovanni Rotondo* and 41,343 in *Vieste*. To set the relative constraint and in contrast to before, a coefficient of 1 is now assigned to the non-hotel tourists and 0 to the other tourist group.

Data on the waste quantities generated in each of the three considered municipalities come from A.S.E. of Manfredonia, which is a private company providing for their waste management service. Estimates carried out to identify the waste disposal capacity specifically serving the tourism sector in each municipality – that is the remaining serving capacity of the field site once having satisfied the need of the local population – show a result of 5,297 kg./day for *Manfredonia*, 4,411 kg./day for *San Giovanni Rotondo* and 9,717 kg./day for *Vieste* (Pazienza, 2001: 60). To set the constraint functions associated to the use of this resource, we assume that while one hotel tourist produces 2 kg./day of waste, each non-hotel tourist generates 1.5 kg./day.

Moving now onto considering the aspect related to the disposal capacity of the sewage purifying systems, data from Acquedotto Pugliese highlight how for the two cases of *Manfredonia* and *San Giovanni Rotondo* there is no serving capacity for tourists. In fact, estimates for these two municipal realities show that the sewage receiving capacities of their respective purifying systems are insufficient to cope with their population's need. Although such a constraint is of stringent importance, we have not taken it into consideration in setting our linear programming problems to the purpose of achieving a solution to the maximisation problem. In the case of *Vieste*, the sewage disposal capacity serving the tourism sector – that is the quantity of disposal capacity remaining once having satisfied the local population's need – has been computed at 2,059 m³/day (Pazienza, 2001: 64). In this case, to set the constraint functions, we follow similar works and assume that generally one hotel tourist consumes 0.4 m³/day of water, while 0.2 m³/day is consumed by one non-hotel tourist (e.g. Canestrelli & Costa, 1991; Van der Berg & Russo, 1997).

Lastly, with regard to car and coach public parking areas, data from each city council shows that 410 places are available in *Manfredonia*, 650 in *San Giovanni Rotondo* and 1,820 in *Vieste*. The use level of this resource by each tourist group has been assumed at a low level for hotel tourists and at a higher one for non-hotel tourists. Such an assumption is based on the conviction that since the non-hotel facilities (camping areas and villages) are often located at a certain distance from the urban centres – this is particularly true in the case of *Vieste* and *Manfredonia* – non-hotel tourists are more bound to the use of their transport tools than hotel tourists who, instead, have the possibility of staying within the urban area. Hence, to fix the constraints associated with the resource in question we assume a use level of 25% for hotel tourists and 75% for non-hotel tourists. On the basis of the arguments and assumptions made so far, the problem formulation for each of the considered municipalities is summarised in the following tables 2, 3 and 4.

Tab. 2 – Problem setting for the determination of the TCC for Manfredonia

Objective function

$$\text{Max } Z = (37.00 - 20.65) \text{ HT} + (7.23 - 5.16) \text{ NHT}$$

Subject to:

1. HB 1.0 HT ≤ 992
 2. NHB 1.0 NHT ≤ 2166
 3. GD 2.0 HT + 1.5 NHT ≤ 5297
 4. SD -- -- --
 5. PP 0.25 HT + 0.75 NHT ≤ 410
-

Tab. 3 – Problem setting for the determination of the TCC for S. Giovanni R.

Objective function

$$\text{Max } Z = (38.73 - 20.66) \text{ HT} + (26.34 - 10.31) \text{ NHT}$$

Subject to:

1. HB 1.0 HT ≤ 3679
 2. NHB 1.0 NHT ≤ 852
 3. GD 2.0 HT + 1.5 NHT ≤ 4411
 4. SD -- -- --
 5. PP 0.25 HT + 0.75 NHT ≤ 650
-

Tab. 4 – Problem setting for the determination of the TCC for Vieste

Objective function

$$\text{Max } Z = (50.61 - 23.82) \text{ HT} + (18.07 - 5.16) \text{ NHT}$$

Subject to:

1. HB 1.0 HT ≤ 3980
 2. NHB 1.0 NHT ≤ 41343
 3. GD 2.0 HT + 1.5 NHT ≤ 9717
 4. SD 0.4 HT + 0.2 NHT ≤ 2059
 5. PP 0.25 HT + 0.75 NHT ≤ 1820
-

The solutions for each of the three considered problems are achieved by using the optimisation solver software Lingo/PC 6.0 (copyright 2001) and are reported in the following tables 5, 6 and 7.

Tab. 5 – Determination of the TCC for Manfredonia

| Objective Function Value | | |
|---------------------------------|-------------------------|---------------------|
| 16840.00 | | |
| Variable | | Reduced Cost |
| HT | 992.0000 | 0.000000 |
| NHT | 216.0000 | 0.000000 |
| Row | slack or surplus | Dual Prices |
| HB | 0.000000 | 30.66667 |
| NHB | 1950.000 | 0.000000 |
| GD | 2989.000 | 0.000000 |
| PP | 0.000000 | 5.333333 |

Tab. 6 – Determination of the TCC for San Giovanni R.

| Objective Function Value | | |
|---------------------------------|-------------------------|---------------------|
| 40296.55 | | |
| Variable | | Reduced Cost |
| HT | 2074.000 | 0.000000 |
| NHT | 175.3333 | 0.000000 |
| Row | slack or surplus | Dual Prices |
| HB | 1605.000 | 0.000000 |
| NHB | 676.6667 | 0.000000 |
| GD | 0.000000 | 16.44444 |
| PP | 0.000000 | 8.444445 |

Tab. 7 – Determination of the TCC for Vieste

| Objective Function Value | | |
|---------------------------------|-------------------------|---------------------|
| 112866.49 | | |
| Variable | | Reduced Cost |
| HT | 3980.000 | 0.000000 |
| NHT | 1100.000 | 0.000000 |
| Row | slack or surplus | Dual Prices |
| HB | 0.000000 | 39.66667 |
| NHB | 40243.00 | 0.000000 |
| GD | 107.0000 | 0.000000 |
| SD | 247.0000 | 0.000000 |
| PP | 0.000000 | 33.33333 |

As we can observe from table 5, in the case of *Manfredonia* the optimal number of tourists which can be daily accepted in the hotel sector is 992 (this corresponding to its total offer). Meanwhile, an optimal number of 216 tourists per day can be accepted in the non-hotel sector (against a total offer of

2,166 beds). This would generate a total profit of around 16,840 Euros per day. Another important consideration can be made for *Manfredonia*. In fact, looking at the solution report, we can still observe the existence of two positive values of dual prices (30.66 and 5.33) which are respectively associated with the two resources represented by the number of beds in the hotel sector and the car/coach parking places. This means that the two resources in question represent the binding constraints to our maximisation problem, that is the constraining conditions to a further improvement of the level of profits from the local tourism sector as a whole. In fact, as reported in the Lingo software user's manual and other technical sources (e.g. Walker, 1999), in a maximisation problem the dual price – or shadow price – can be interpreted as the amount by which the objective function would improve as the right-hand side or constant term of the related constraint is increased by one unit. In other words, dual prices tell us how much one should be willing to pay for additional units of a resource. From this evidence, and referring back to our *Manfredonia* case, the two resources associated with the positive dual prices must be considered scarce. Hence, it would be an appropriate policy indication to enlarge the receiving capacity of these two scarce resources to relax tourism pressure on the corresponding facilities and to give some more space to a further improvement of the economic performance of the local tourism sector. Since the enlargement of hotel facilities is often left to private initiative, any eventual action of local public spending can be undertaken to enlarge the carrying capacity of parking areas.

With regard to *San Giovanni Rotondo* the optimal number of tourists which can be received in the hotel sector is 2,074 per day (against a total local offer of 3,679 beds). Instead, in the non-hotel sector, the optimal number which can be daily received is about 175 tourists (against a total local offer of 852 beds). This considered, the amount of profit which can be generated daily by the entire local tourism sector is about 40,296 Euros. In this case two binding constraints can be observed in relation to the carrying capacity of the field-site for waste disposal and parking areas. Since these two facilities are generally provided by the public sector, public expenditure can be used for their enlargement.

Finally, moving onto analysing the problem results for *Vieste*, it is possible to observe that in the hotel sector a daily optimal number of 3,980 tourists can be accepted (this being exactly equal to the existing local offer of hotel beds). Furthermore, in the non-hotel sector, the optimal tourist number which can be daily received is 1,100 (against a total local offer of 41,343 non-hotel beds). On this basis, the daily profit level which can be generated daily by the entire local tourism sector is about 112,866 Euros. Even in this case, two binding constraints can be identified. One regards the number of beds in the hotel sector. The other is related to the capacity of the parking areas. Here again – as we have discussed in the case of *Manfredonia* – public expenditure activity can be suggested to enlarge the carrying capacity of parking areas while leaving the enlargement of the hotel capacity to the private sector initiative.

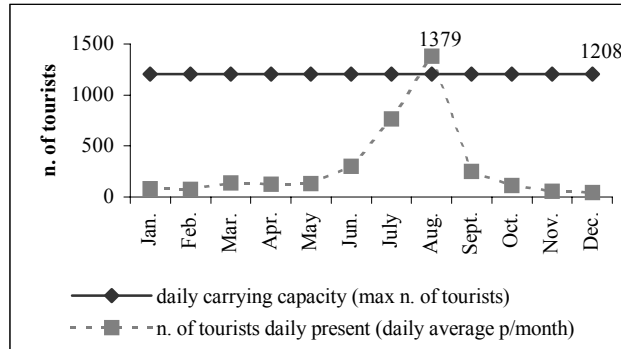
6. EVIDENCE OF UNSUSTAINABLE USE OF THE GARGANO RESORTS

From the analysis we have carried out in the previous section – where TCC thresholds have been identified with respect to the hotel and non-hotel sector – we can now observe how each of the considered municipalities can host an optimal number of tourists per day. For simplicity, by adding the results related to the hotel sector to those of the non-hotel one, we can firstly verify that *Manfredonia* has a total tourism carrying capacity of 1,208 tourists per day. The total tourism carrying capacity per day for *San Giovanni Rotondo* is 2,249 tourists. Furthermore, with regard to *Vieste*, a total tourism carrying capacity of 5,080 tourists per day can be observed. If we now proceed to compare these carrying capacity values with reference to the daily presence of tourists, we can gain an idea of the times and size in which the number of tourists present at a destination has overtaken the computed carrying capacity thresholds.³

³ To this purpose, it would have been more appropriate to use specific data on the daily tourism presence observed at destinations. However, due to the unavailability of such information – the local tourism office (APT of Foggia) was unable to supply us with this type of data – we compute a per month daily average of the tourist presence as of year 2002.

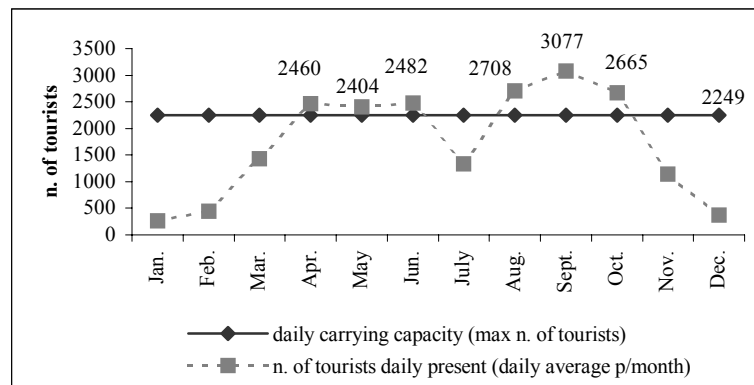
By firstly analysing the case of *Manfredonia*, the graph presented in figure 2 shows how the tourism flow has overtaken the computed carrying capacity level of 1,208 tourists per day during the month of August. Indeed, an average of 1,379 tourists per day can be observed in this month.

Fig. 2 – TCC and tourism flow in Manfredonia at 2002



Moving onto considering the tourism destination of *San Giovanni Rotondo*, it is possible to see that the recorded data shows the highest peaks of daily tourism presence in September. In fact, in that period a daily average of 3,077 tourists is observed. It is also possible to see that in the considered year the TCC threshold is overtaken in correspondence of April, May, June, August and October. Although it seems as though the average daily level of tourism presence slightly overtakes the daily carrying capacity threshold (2,249), it must be stressed that *San Giovanni Rotondo* as a tourist resort shows the characteristics of being a destination for day-trippers as well as for holidaymakers. If we consider that the number of day-trippers is much larger than normal tourists, it is clear that the computed carrying capacity threshold is greatly overtaken.⁴ Figure 3 graphically shows the observed situation for the municipality in question.

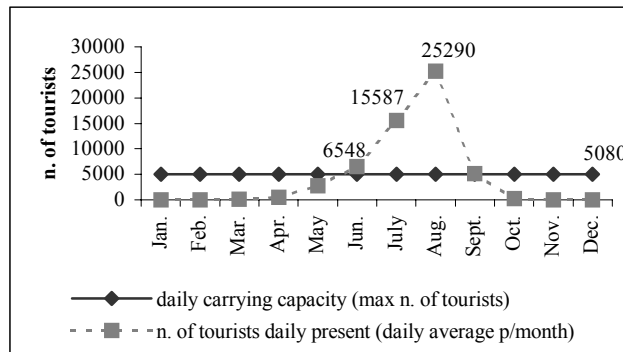
Fig. 3 – TCC and tourism flow in S. Giovanni R. at 2002



Looking at the case of *Vieste*, a very severe situation can be observed. We can observe how the computed daily average of tourism presence enormously overtakes the daily tourism carrying capacity threshold for a large period of time during the year. Indeed, as the graph in figure 4 shows, from June the level of tourism presence is always above the limit of carrying capacity. The highest peak is recorded in August when the average tourism presence is 25,290 individuals per day, while the carrying capacity limit is 5,080 tourists per day.

⁴ As reported by one study from the Polytechnic of Milan (2000: 21), the records on the total tourist numbers arriving in *San Giovanni Rotondo* and staying in either hotel or non-hotel infrastructures represent a minimum part (less than 10%) of the real flows. In fact, as they state, the majority of people are day-trippers – mainly pilgrims – who are estimated to be four million per year.

Fig. 4 – TCC and tourism flow in Vieste at 2002



As we have already discussed for the case of *San Giovanni Rotondo*, this analysis does not take into account the tourism phenomenon of day-trippers due to a great lack of statistical information regarding its trends. Furthermore, as stated by ATP, there is strong evidence to suggest that at least 50% of the tourism flow arriving at Gargano destinations is statistically unseen. Hence, considering such aspects, we can appreciate how tourism presence at the considered destinations actually overtakes the identified tourism carrying capacity thresholds in an even greater way than we have showed in this section. As a consequence, a considerable negative impact on the analysed local environments from tourism can be easily perceived.

7. CONCLUDING REMARKS

In this work we have used an example of a multidimensional model for the computation of the TCC and an effort has been made to test its empirical application at some of the most important tourism destinations of the Gargano National Park in the region of Puglia in Southern Italy. We have found evidence of unsustainable use of the tourism resorts which appears to be particularly strong in one out of the three investigated municipalities. In fact, during the summer months in *Vieste* the tourism presence greatly exceeds the optimal threshold of its computed carrying capacity per day. The same evidence could also be confirmed in the cases of *Manfredonia* and *San Giovanni Rotondo* for which, as appropriately argued and with the aim of bringing the TCC computation models to a solution, we have relaxed the constraints related to the capacity of their respective sewage purifying systems.

From what we have just said it appears that the identification and choice of the constraint functions – which represent the resources or the limiting factors on which the considered tourism destinations are based – is a question of value judgements, which are generally subjective. Hence, the risk of wrongly developing and calibrating a model is real. If so, the achievement of misleading results and wrong policy indications would be a natural consequence. Nevertheless, models for the search of numerical based measures of TCC should not be considered as something useless or obsolete since, if adequately built, they can help us to obtain valid indications on how to organise tourism development and/or management plans. In fact, if they are used with scientific wisdom and implemented with a multidimensional approach they could be considered as an important tool in understanding which direction public and private investments should go to achieve adequate and sustainable development/management of the local tourism sector. With regard to this, it must be considered that investment in enlarging the capacity of some subsets in the tourism sector (such as that of a field site for garbage disposal or a sewage purifying system) can also generate less impact on the biophysical and social contexts of the territory and induce a general improvement of the quality of the local environment.

Before concluding, we would like to highlight some limits existing in the model we have presented in this work. In fact, we are conscious that a more complete approach to developing it would require enlarging the number of the considered constraints. This would allow us to take into consideration

other aspects such as those more strictly related to the conditions characterising the biophysical and social spheres of local hosting communities. However, as already argued, the lack of valid information on these aspects and the difficulty in collecting it has not enabled us, at this stage, to provide more constraints. This requires us to call for further empirical and multidisciplinary research in the aim of finding significant explanations to describe, at a local level, the relationship between tourism and the biophysical and social spheres.

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