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### DIE DEMONSTRATORS FOR THE TOOLING INDUSTRY

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**Abstract.** *Although Brazil is a producer of stamping tools, most of the Brazilian market is dominated by Asian producers, and Brazilian tooling companies respond only for 0.4% of the global market. When producing die tools for the automotive industry, few Brazilian tool shops are considered apt to produce high complexity parts subjected to strict quality requirements, such as class A surfaces and B columns. To improve the competitiveness of the Brazilian tool shops, the Route 2030 Brazilian Program set up a specific line for funding research projects related to this sector, called Ferramentarias Brasileiras Mais Competitivas (in English More Competitive Brazilian Tool Shops). This line is composed of four axes, among which the first three support the development of technologies at different TRL (Technologies Readiness Levels). The fourth axis is related to the setting up of demonstrators that should be used as a reference to identify bottlenecks for the Brazilian tooling industry competitiveness. In this context, this paper describes the methodology adopted for setting up two demonstrator projects: DEMESTAA – Demonstrador de Estampagem de Superfícies Classe A (in English, Class A Surface Die Demonstrator) and DECOLAB – Demonstrador de Estampagem de Coluna B (in English, B Column Die Demonstrator). The paper describes the organization of a consortium encompassing more than 20 industrial partners, including representatives from material suppliers, service and software suppliers, tool shops, automotive OEMs, among others. It presents the project organization and the role and contributions expected from the project partners. It examines the complementary role of the two leading Institutes of Science and Technology in the project: ITA and FGV. It discusses the concept and requirements of a “demonstrator” project to achieve the purposes of the Route 2030 Program. Furthermore, it shows the results in identifying bottlenecks for the Brazilian tooling industry competitiveness and describes future activities.*

**Keywords:** *tool shops, die industry, automotive industry, Route 2030, management of innovation.*

#### 1. INTRODUCTION

The Route 2030 Program is oriented to the automotive industry and is an evolution of the previous initiative, the Inovar-Auto, regulated by the “Decreto 781” from 3rd October 2012 (BRASIL. Presidência da República 2012). The Inovar-Auto has required an investment of 0.5% of the Gross Operating Income of each vehicle company in research and development in Brazil. The investment was discounted from the IPI (tax on industrialized products) when the car companies fulfilled some specific obligations (fundamentally investing in RD&I). The success, as well as the lessons learned, allowed progress towards an evolved program. Route 2030, regulated by the “Decreto 955” (BRASIL. Presidência da República 2018), was established in 2018, and the most significant difference is that it was expanded for the whole automotive sector, not limited to car companies only. Route 2030 aims at supporting technological development, competitiveness, innovation, vehicular safety, environmental protection, energy efficiency, and the quality

of vehicles. A significant improvement of Route 2030 is that the funded projects obligatorily demand the engagement of ISTs (Institutes of Science and Technology) and the partner companies. The Program Route 2030 is divided into four programmatic lines, each with its theme and objective (BRASIL. Ministério da Economia 2019):

- Line-I: Increase the productivity of the automotive supply chain, including self-propelled agricultural and highway machinery,
- Line-II: Process automation, industrial connectivity, and advanced manufacturing in the automotive supply chain, including self-propelled agricultural and highway machinery,
- Line-III: Increase the investment in research, development, and innovation in the automotive supply chain, including agricultural and self-propelled highway machinery,
- Line-IV: Strengthen the automotive tooling and mold chain, and
- Line-V: Stimulate the production of new biofuels, vehicle safety, and alternative combustion propulsion technologies.

In this context, the study of this paper is enclosed into two projects of the Line-IV of Route 2030: DEMESTAA - *Demonstrador de Estampagem de Superfícies Classe A* (in English, Class A Surface Die Demonstrator), DECOLAB – *Demonstrador de Estampagem de Coluna B* (in English, B Column Die Demonstrator). A consortium was formed for these projects encompassing more than 20 industrial partners, including representatives from material suppliers, service and software suppliers, tool shops, automotive OEMs, and others. The Line-IV of Route 2030 is subdivided into axes:

- (i) Improvement and implementation,
- (ii) Research, development, and innovation,
- (iii) Disruptive research and development, and
- (iv) Development from demonstrators.

Both DEMESTAA and DECOLAB projects belong to the fourth axis.

The first three axes sustain the development of different TRL technologies (Technologies Readiness Levels). The fourth axis objectifies learning with the current practices of the Brazilian tooling industry by making demonstrators that would work as Brazilian tooling state of the art and, therefore, as study cases for the identification of technological, organizational, and methodological bottlenecks, hence making it possible to propose future projects based on those identified topics (Fundep 2020).

The overall goal of Route2030's Line-IV is to increase the national tool shops' competitiveness against global competitors. The die market yearly turnover is around 42 billion dollars, and the Brazilian tooling industries take part in only 0,4% of this share (Gomes 2018). A sense of necessity for action is perceived in the statement of the Brazilian Tooling Industry Association –ABINFER's President, Mr. Christian Dihlmann, when he says that“there must be a technological leap forward in the Brazilian industrial park, so to gain competitiveness” (Dihlmann 2018). With approximately 2000 tool shops, car companies with nationally located factories still buy overseas, which is understood as a consequence of price and deadline advantages offered by offshore competitors and the small national production capacity. In 2018, Asian tool shops would offer dies nearly 20% cheaper than those sold nationally, and Brazil would have to increase its production capacity four times to supply the car companies' demands (Dihlmann 2018).

The present work has two noteworthy contributions: explaining functional aspects and replicable procedures of the organization of the consortium for the projects DEMESTAA and DECOLAB, which, with more than 20 industrial partners, presented innovation management challenges and introducing preliminary results of the projects' identification of bottlenecks for the national tooling industry competitiveness.

This paper is structured as follows. Section 2, entitled Projects' preparation and consolidation, focuses on the management of the projects. Section 3, entitled Identification of bottlenecks for the Brazilian tooling industry competitiveness, shows the results already achieved in the projects and the methodology used. Finally, Section 4 summarizes lessons learned and conclusions.

## 2. PROJECTS' PREPARATION AND CONSOLIDATION

Before their formalization and execution kick-off, a considerable effort was put into completing the requirements of the proposals for DEMESTAA and DECOLAB. The effort required was related to the management of innovation processes, with activities towards identifying and prospecting potential industrial and academic partners, understanding the tooling and automotive sectors' context and demands, defining work packages to execute the projects according to their objectives, and deliberating roles for each member throughout those work packages, among other specific activities that are discussed in the following sections. Section 2 is subjected to a bias from the authors since they learn from an environment and experiences they are subjectively included.

## 2.1 The construction process of a consortium for a demonstrator proposition

A demonstrator shall establish a way to observe the object of study, apart from the actual process. As ITA and FGV do not take part in the tooling market, it was understood that the partnership with companies of the tooling sector would be positive in learning about the tooling life cycle. Therefore, the first approach was to use the network of both IST to contact companies of the representative phases of the tooling construction: car companies, tool shops, project offices, software suppliers, and components suppliers. As car companies became acquainted with the idea of the project, the network expanded with their networks, and other companies were contacted. After each company was co-opted, the network was increased, and new companies could be reached. This approach to network expansion is depicted in Figure 1.

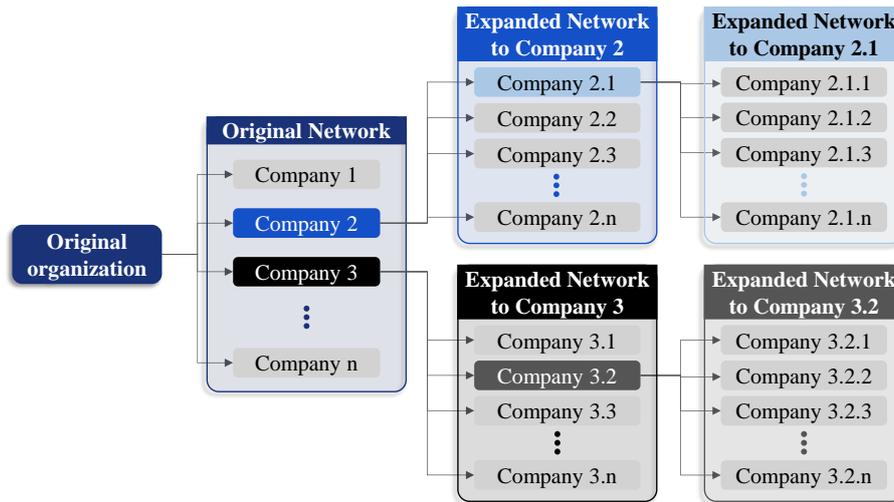


Figure 1. Simplified network expansion map of the companies of the tooling sector.

The representative sectors of the tooling industry are depicted in Figure 2. Suppliers differentiate themselves by product suppliers, which offer necessary components to manufacturing tools, from the prime material to Nitrogen cylinders, and service suppliers, such as Die Engineering and Die Design, casting, and intermediate machining. The tool shops are the primary manufacturers, and they are generally the suppliers of the tooling to the final users. The users are mainly the car companies and several car systems companies, such as companies that produce shafts, wheels, and other parts. The scheme of Figure 2 is an example and does not represent the entire chain in detail, but it is sufficient to visualize the critical players contacted during the projects' prospection. The partnership with virtually all sectors of the die and molds chain promoted learning of the sector before submitting the final proposal and during the projects' DEMESTAA and DECOLAB activities.

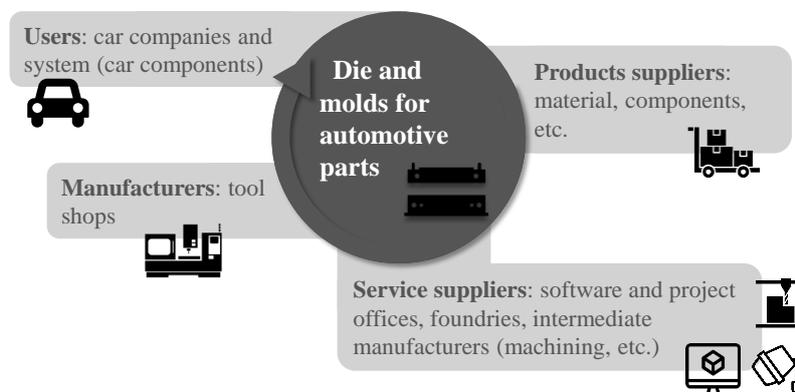


Figure 2. Die and molds industry prospected sectors.

The final version of the consortium is composed of 24 companies and three ISTs. Figure 3 illustrates both projects organization and their participants: six tool shops, six car companies, seven suppliers of software and project, one car system company, one material supplier, and two components' suppliers. Their leaders are: the Aeronautics Institute of Technology – ITA for DEMESTAA and the Getúlio Vargas Foundation – FGV for DECOLAB. The National Service of

Industrial Learning – SENAI is an associated institution. The Institute for Research and Technology – IPT is the Route 2030 Line-IV coordinator, and the Research Development Foundation – Fundep is the resources management.

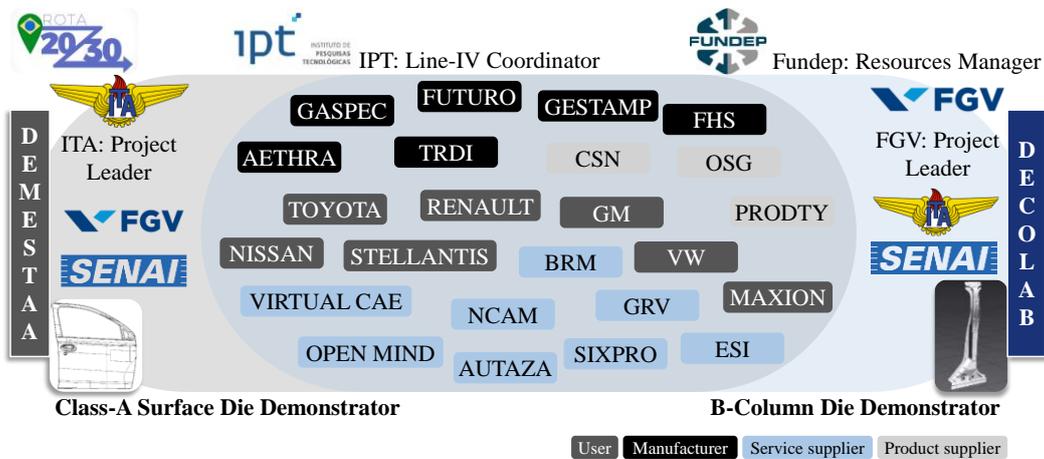


Figure 3. The DECOLAB and DEMESTAA consortium.

## 2.2 Challenges for the projects formalization phase

To formalize the projects and partnerships, many companies have had to move a complex internal circuit to collect the required signatures to the contract, increasing the response time to deliver the signed contract (Figure 4). Not the case for smaller to medium companies, where the response time took an average of three to nine working days. However, for car companies especially, the response time took, on average, 30 to 45 days. Despite some exceptional cases that were observed, where medium companies needed more time to sign the contract than large ones, hence the importance of understanding that each company has its specific organizational signature circuit, one can expect, on average, that the larger the company, the higher would be the response time. Other aspects can influence the response time, for instance, duties to international counterparts of companies with their matrices overseas, level of confidential information of company's counteroffer, and the aspects of the market – if it is a heated market, some companies could have delays due to overload workers. The ISTs are responsible for the prospection, which means the whole team of coordination professors, students, and researchers was involved in managing the contracting process.

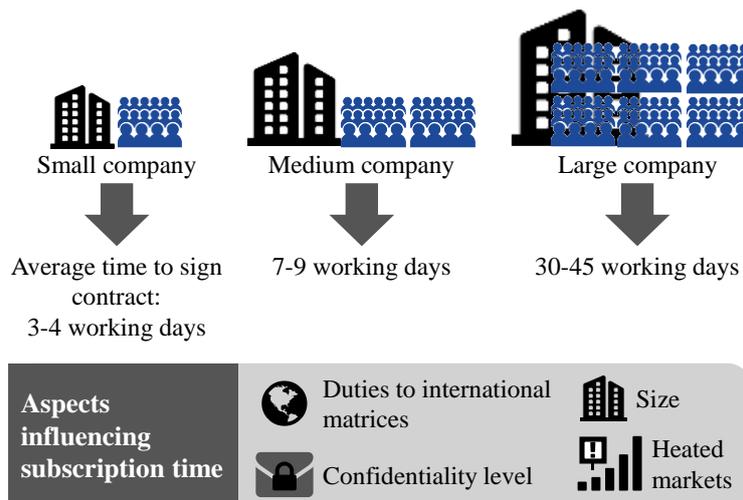


Figure 4. Subscription average time for companies of different characteristics.

## 2.3 Complementarity of ITA and FGV as Innovation Managers

The presence of two Institutes of Science and Technology in the coordination has made integrated management possible. Both institutions complement themselves with their specific skills, which opens the possibilities for these and future projects. The success of this initiative will indicate the potential of this approach. The model where both institutions

work together is already showing results, intangible but perceived (Figure 5), in terms of organization, knowledge exchange, and crossing organizational culture habits. The ecosystem created with the consortium (Figure 3) brought to both institutions close contact with the companies, enabling their complementary competencies to be quickly adjusted during the two projects' execution because both institutions simultaneously worked with the partners.

In the first three months of the projects, the consortium ecosystem reached stability, with weekly or biweekly General Meetings organized by ITA and FGV that every one of the 28 partners should attend to learn about the projects' updates and discuss the next steps. During the first phase, creating a purchase order specification for the demonstrators, it was necessary to schedule weekly meetings with the companies experienced in ordering die and molds, the users (Figure 2), and the ISTs. Other meetings about specific topics happened with other groups of companies related to such topics. For instance, several meetings with simulation companies took place to discuss the conception phase of the tooling construction cycle, the Die Engineering, and Die Design to find opportunities for investigation regarding process optimization through simulation.

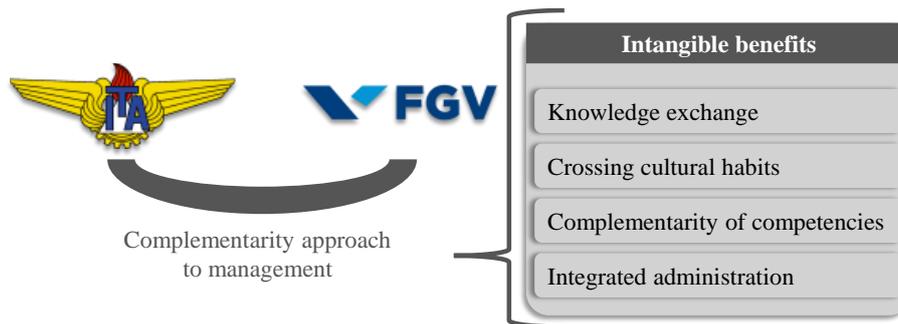


Figure 5. Intangible benefits of complementarity approach to the projects DEMESTAA and DECOLAB, by ITA and FGV.

## 2.4 Opportunities

Following the benefits of the use of large consortium projects as the ones explored in this study, the authors highlight the opportunities that might come from this practice:

- To use this consortium as a model for new project proposals. Despite the challenges faced when managing many industrial partners, large alliance projects might promote advantages obtained from several industrial partners working together and representing entire sectors.
  - Mainly: sector representativeness, network expansion, cultural crossing habits, knowledge exchange, and product-oriented research (due to the high amount of practical experience inside the consortium).
- To participate in open consortiums after they had begun. The projects explored in this study are already being executed; however, they are still open to interested partners that can contact the authors for further information. The same can happen over time with other Route 2030 or consortium projects. This possibility of late entry is a positive characteristic facilitated in consorcial projects with an extended range of participants.

## 3. IDENTIFICATION OF BOTTLENECKS FOR THE BRAZILIAN TOOLING INDUSTRY COMPETITIVENESS

Some dynamics (Figure 6) were proposed to identify bottlenecks and their possible solutions. The dynamics were planned to be performed with the companies' representatives and the ISTs to discuss and learn together. The first phase is composed of individual interviews with the companies to identify the problems in the tooling market that are barriers to the tool shops' competitiveness against international players. This phase's results are presented in this paper. The second phase is intended to highlight possible technology solutions or innovation drivers with good potential to undertake the already identified problems. The third and fourth phases will be performed together in the same meeting, uniting two or more companies to discuss the possible approaches and exchange experiences.

In parallel to the already mentioned General Meetings of the projects DEMESTAA and DECOLAB, the first phase's meetings (interviews) took place. The interviews were done with 21 companies, representatives of four sectors of the tooling industry: six car companies, eight tool shops, five service suppliers, and two product suppliers. The methodology for the interviews and some insights on the data processed are presented in section 3.1. Section 3.2 presents the results.

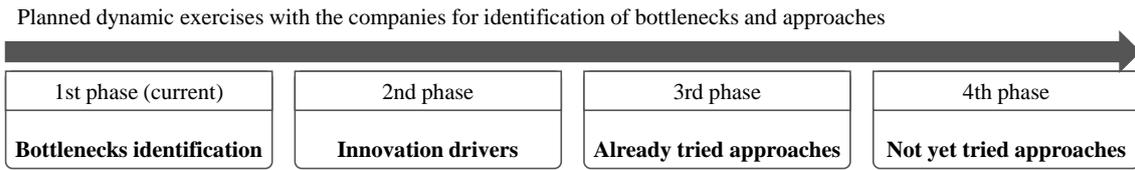


Figure 6. Dynamic to identify bottlenecks and possible solutions.

### 3.1 Methodology of bottlenecks identification

Online individual meetings for the 1<sup>st</sup> phase (Figure 6) happened with one company at a time, with a maximum of three persons from the company and four persons maximum from the ISTs. The conversation revolved around one single question, “What are the bottlenecks for the competitiveness of the national tooling industry?”. The interviewer was not allowed to influence the interviewees’ responses, and the job was to take notes and moderate the discussion. The other participants from the ISTs were allowed to give their opinion, taking care not to bring ideas before the interviewee did, and commenting only about the points the interviewee had already spoken. The practice of not introducing new ideas before the interviewed person does is essential to avoid learning about the interviewer’s ideas of the bottlenecks but to learn what the companies’ representatives picture of their experience as explained by Roulston (2016) as practical implications in interviewing research.

The interviewer synthesized the discussed topics into small sentences – the bottlenecks, writing them during the meeting, and sharing the screen so that interviewees could see. Similar issues were raised in different interviews, and when possible, they were allocated as the same bottleneck. The interviewees were encouraged to adjust what was documented, to meet what they meant with their statements.

Regarding the representativeness of the interviewed people, the decision was to interview experienced workers of the companies, which can make reasonable assumptions about the whole picture of tooling industry challenges. The majority of the participants were managers or directors from the areas of sales and engineering. The sample size of 21 interviews was limited only by the number of companies participating in the projects but stayed inside the range proposed by Marshall et al. (2013). The fact that the interviews encompassed all tooling manufacturing chain players identified in Figure 2 reinforces the results’ effectiveness in understanding the tooling sector’s bottlenecks. Nevertheless, the authors are aware that more qualitative research can be done to improve the representativeness of the entire sector.

To guide interviewees without interruptions and little influence, the authors used the tooling general process map depicted in Figure 7. The map is a representation of the tooling construction cycle that was divided into four phases: Conception, with Die Engineering – product characteristics, process stages validation and Die Design – tooling project in two and three dimensions, press transference, full-cycle simulation; Manufacturing, with all the manufacturing processes, Styrofoam model, casting, machining, and assembly; Internal Tryout, with first part analysis and corrections; and Client Tryout for adequacy to production presses. Many attendees identified bottlenecks based on the order of each cycle’s phase.

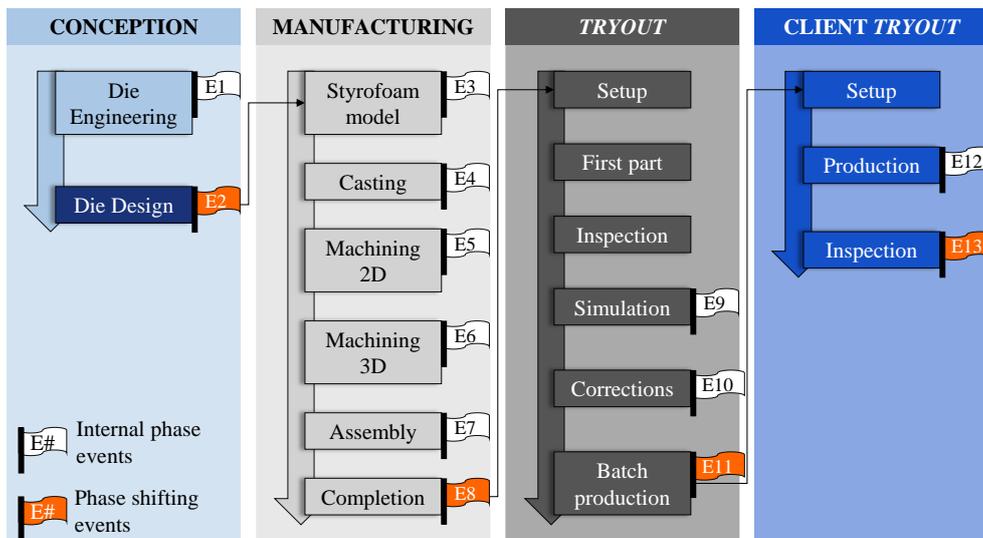


Figure 7. Tooling general process map.

### 3.2 Results

In total, a surprising number of 81 bottlenecks were identified for the national tooling industry competitiveness. As more than 30 appear only once, it is more efficient to fit all bottlenecks to themes they relate together for better visualization. Therefore, the 81 bottlenecks were classified into nine groups (each bottleneck being only in one group), regarding their common thematic:

- i) “Capacitation & Workforce” brings bottlenecks related to the availability of specialized workforce, labor retention, and quality of the specialization courses available.
- ii) “Brazil’s relative cost” groups the bottlenecks related to increased costs on the tooling construction that happens only in a national scene, e.g., cost of national steel, lack of a national center for the tryout, and high taxation of components.
- iii) “Suppliers’ availability & quality” is related to the number of national suppliers (Styrofoam model, Die Design, machining, among others), their schedule to delivery, and the quality of the service compared to global competitors.
- iv) “Casting quality & production capacity” corresponds to the bottlenecks identified regarding the casting phase, availability of suppliers in a heated market, quality of the product in comparison to what is available globally, among others.
- v) “Machinery & Equipment” groups the points cited regarding underutilization of machines and equipment, availability of machines, outdated machines.
- vi) “Simulation” is entirely related to simulation aspects, with complaints like simulation is not assertive or is not used as a cost-reduction tool.
- vii) “Management” gathers the bottlenecks regarding specific points of the management on tool shops, like inefficient technology adaptation, the nonexistence of lean manufacturing techniques, lack of cooperation between tool shops, among others.
- viii) “Sales, requirements & procedures” for the relation between players, sales processes, and technical and non-technical requirements. Examples are that overly protective order specifications end up increasing prices, delays on biddings happen very often, and dimensional and surface tolerances are getting unpractically smaller.
- ix) “Other” collects all bottlenecks that are too general to fit in any other group. Some of them are the highly uncertain demand and the lack of systematization of conception phases.

The companies cited a total of 179 problems during the interviews. Among them, 81 bottlenecks were identified, 35 were cited by two or more company representatives, and 46 were cited only once. Figure 8 shows the number of times a bottleneck group is cited. The Group (i) Capacitation & Workforce is the most cited one, followed by the (v) Machinery & Equipment, and the (iii) Supplier’s availability & quality tied with the (vi) Simulation.

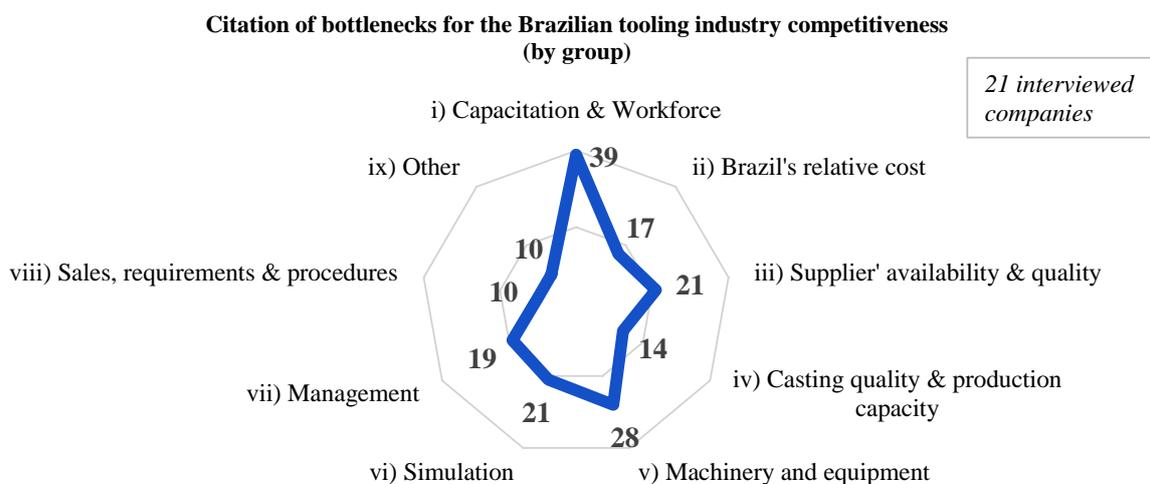


Figure 8. Frequency of bottlenecks’ groups’ citation by 21 companies of the different sectors of the tooling manufacturing chain. The bottlenecks totalize 81, and the most cited group is (i) Capacitation & Workforce.

Some bottlenecks stood out in the number of citations (Figure 9). More than half of the companies showed concern about the quality of the machine tools in the Brazilian tooling market and stated that this is a jam to competitiveness and that machines should be updated to get to better dimensional results and reduce machining timing. The bottleneck regarding outdated machinery is a problem related to another bottleneck. The interviewed representatives pointed out the “highly uncertain demand” as the cause for the tool-shops not allocating resources to buy new machinery. The highly uncertain demand seems to happen for different reasons, mostly because users import tools from other countries, so tool shops do not have long-term stability predictions.

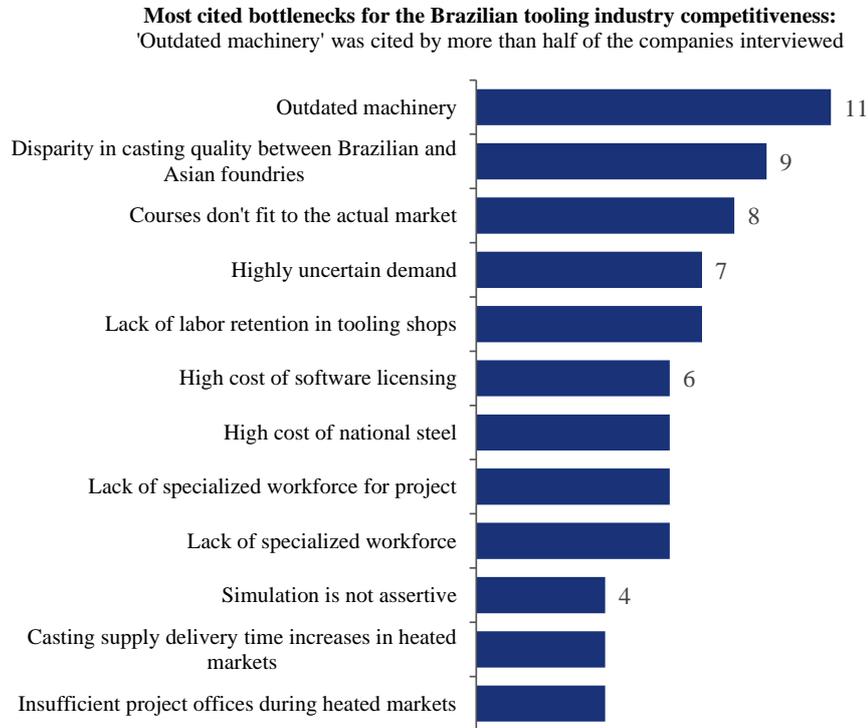


Figure 9. Most cited bottlenecks.

The second most cited bottleneck is a warning to the quality of casting products produced in Brazil, which directly affects the chronogram of tool making. Most problems related to casting were the porosity, unwanted inclusions, and thick over metal left on the parts. Those issues compromise the forward phases of tooling manufacturing, especially the machining phase, and are often derived from the bad quality of the prime material used on the casting process and linked to necessary improvements on the casting process performed by national suppliers. Moreover, companies have stated that due to the small number of foundries, when the demand is high, the delivery of casting suppliers is also compromised, delaying the entire chronogram. The demand oscillation happens in the tooling market because of the introduction of a considerable number of orders when a new car is to be released, which abruptly increases the demand for every player of the production chain. The new orders are very good for all the companies, as demand is attractive, but the oscillation's existence causes the problems. When the market is heated, most of the companies composing the tooling chain suffer from schedule alterations.

The “Courses don't fit the actual market” added to “Lack of labor retention on tool shops”, “Lack of specialized workforce for project”, and with “Lack of specialized workforce” some a total of 27 citations, showing a concern with specialization of the workforce. This matter was cited at all the interviews and stood out in Figure 8, with Group (i) the most cited. The great concern of the companies interviewed shows that the remediation of this issue has good potential to improve the competitiveness of the Brazilian tooling market. Companies gave some ideas during the interviews for introducing different items on the already existent undergraduate/technical courses: the adoption of practical exercises with software for simulation of stamping processes and the inclusion of specific subjects related to the tool manufacturing processes.

Regarding simulation phases, the most cited bottleneck was related to the costs of the software licensing. The subscriptions are yearly and practiced in the currency of the software company supplier, which is often Euros or Dollars. The high cost added with an unstable demand outcome on the tool shops not being able to maintain the simulation phases internally, which is a cause of other problems, like a lousy learning curve, and the inferior knowledge management, both influenced by many subcontracting, leaving knowledge outside the tool shops. The simulation was also said to be “not

assertive” by four companies. The assertiveness of simulation is essential to reduce the effort spent in tryout phases and avoid adjustment loops. This issue regarding simulation reliability highlights the potential of training skilled workers for this field of study.

The cost of the steel to be bought nationally was also considered a bottleneck by some companies. That directly affects the total cost of the tool and, with increasing costs and unpredictability, is another barrier to long-term planning for tool shops. Therefore, this is a bottleneck that affects the main cost of the tools and reduces the chances for the tool shops to invest in new machinery, automation technologies, and more efficient processes.

#### 4. CONCLUSIONS

This paper discussed organizational aspects, from the prospection until the early execution stages of the projects, with a presentation of the results of identifying organizational, methodological, and technological bottlenecks for the Brazilian tooling industry competitiveness. The conclusions are limited by the sample adopted. Twenty-one companies were interviewed, among many other that exist in Brazil. It is also subjected to a bias from the authors since they are learning from an environment where they are included and exposed to qualitative interviewing research aspects. The significant contributions of this paper are:

1. The authors conclude in favor of increasing the management of innovation in projects, using network expansion as a tool to build large consortial projects, integrated and complementary management by two or more ISTs. Collaboration with industrial partners is also crucial for ISTs to gain/grow their knowledge about specific sectors and research lines.
2. By the knowledge acquired at this early phase of Route 2030’s projects, the demonstrator definition can be set as “the establishment of a way to observe the object of study, apart from the real process”. Additional information will be collected during the subsequent phases of the project, and this concept might be updated.
3. The model of consortial projects explained in this study and its benefits can be used to generate new proposals and partnerships.
4. Route 2030 Line-IV has an overall goal to increase the Brazilian tool shops’ competitiveness against global competitors. The projects cited in this study share the same objective to which the results presented in section 3 are related. The results showed that the bottlenecks most significant to the tooling industry might be matters regarding education, availability of workforce, outdated machinery, casting quality, oscillating demand, costs predictability of steel, simulation reliability, and knowledge management. The subsequent investigations will revolve around technological drivers and possible solutions to the identified problems.
5. Classifying the bottlenecks by groups proved its functionality, facilitating the data visualization and learning with the results. The nine groups can be used again in further researches of the matters.

#### 5. ACKNOWLEDGEMENTS

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